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NORTH-WESTERN AREA COMMITTEE
FOR 1930—1932

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CONTENTS

Preface.

I. Probable Influence of Changes in Temperature on the Marine Fauna of Iceland, by Dr. Bjarni Saemundsson, Reykjavík. (1—6).

II. Synopsis of Investigations into Fluctuations in the Stock of Cod at Greenland during the Years 1930—1933, by Paul M. Hansen. (1—11).

III. Danish Hydrographical Investigations in the Denmark Strait and the Irminger Sea during the Years 1931, 1932 and 1933, by Helge Thomsen. (1—14).

IV. Marking Experiments with Plaice in East Icelandic Waters, by Å. Vedel Tåning. (1—14).

V. Report concerning the Analysis of Cod Otoliths from Iceland, by Árni Friðriksson, Paul M. Hansen, Anton Fr. Bruun and Å. Vedel Tåning. (1—14).

VI. On the Calculation of Age-Distribution within a Stock of Cod by Means of relatively few Age-Determinations as a Key to Measurements on a large Scale, by Árni Friðriksson, Reykjavík. (1—5).

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PREFACE

The present report of the North Western Area Committee was under preparation when the Chairman of the Committee, Professor Johs. Schmidt, died on February 21st 1933. Circumstances prevented the report being printed in time for the Council Meeting in Paris, and at the meeting of the North Western Area Committee on May 10th it was therefore decided to again recommend the publication of the report which recommendation was sanctioned by the Council (cf. Rapp. et Proc.-Verb. Vol. LXXXV, 1933, part 1, p. 15 and 31). As the printing of the report thus had been delayed until the late autumn I have considered it necessary, as far as two of the treatises are concerned, to ask the authors to include in their publications such important material as had been collected during the summer of 1933, their value to the reader being considerably augmented by the fact that the treatises are brought up to date.

It had been the intention of Professor Johs. Schmidt to publish in this volume of the report of the Committee a synopsis of certain work carried out in the North Western Area during recent years where amongst others the marking of cod had given interesting results, but he did not succeed in carrying out this scheme before he was overtaken by illness and death and I am sorry to say that amongst his papers we have found no draughts for this work which he had mentioned to me but which he had evidently not begun to write down.

It is a well-known fact that during many years Professor Johs. Schmidt entertained the greatest interest in marine-biological and hydrographical investigations of the Northern Atlantic from Greenland to the Bay of Biscay and a great number of important publications in the Rapports et Procès-Verbaux as well as in the publications of the Danish Committee for the Study of the Sea (see: List of Professor Johannes Schmidt's Scientific Papers 1899—1932 "Journal du Conseil" Vol. VIII, No. 2, 1933, p. 153—) bear witness thereto. No other scientist has reached his importance as concerns the fishery-biological investigations in this area, his work on the *Gadidae*, for instance, which included a description of the development, distribution and biology of nearly all the North Atlantic species belonging to this family, has formed the foundation of all later investigations of this important group of fish in the above mentioned area. Already in 1904 Schmidt's researches concerning the distribution of the postlarval stages of the Gadids in the North Atlantic carried him into investigations of the biology of the fresh-water eel and these, again, made him gradually extend his oceanographical investigations to all the oceans; especially the investigations on the fresh-water eels spread his fame to all the countries of the world. It was, therefore, a matter of course that, when in 1923 the Council appointed the North Western Area Committee, Schmidt became its chairman, a position which he retained till his death.

In Rapports et Procès-Verbaux Vol. XXXIX, LVII and LXXII as well as in the annual administrative reports of the Committee Schmidt in his position as chairman has edited all the contributions supplied by the members of the North Western Area Committee concerning investigations carried out in this area which above all others possessed his interest, probably accentuated by the fact that his first laurels were won in these waters when, as a young, enthusiastic marine-biologist, he was the leader of the "Thor"s cruise of 1903, the first scientific fishery-biological expedition to these distant northern areas.

It is not, however, my intention to give in this place a description of the life and the scientific work of Professor Schmidt, a more detailed account being found elsewhere in the publications of the Council [Procès-Verbaux Vol. LXXXV p. 9 and following pages (by the President, Mr. H. G. Maurice, and by Professor L. Joubin); Journal du Conseil p. 145 (by Dr. C. Tate Regan)], but to preface this volume concerning the reports of the work of the North Western Area Committee with the above words emphazising the great importance of the work of Professor Schmidt in this area — coupled with my sincere regrets that after thirty years' work in the areas round Iceland and the Faroes time was not granted him to leave us a résumé of the work to which he had devoted his whole life.

Å. Vedel Tåning.

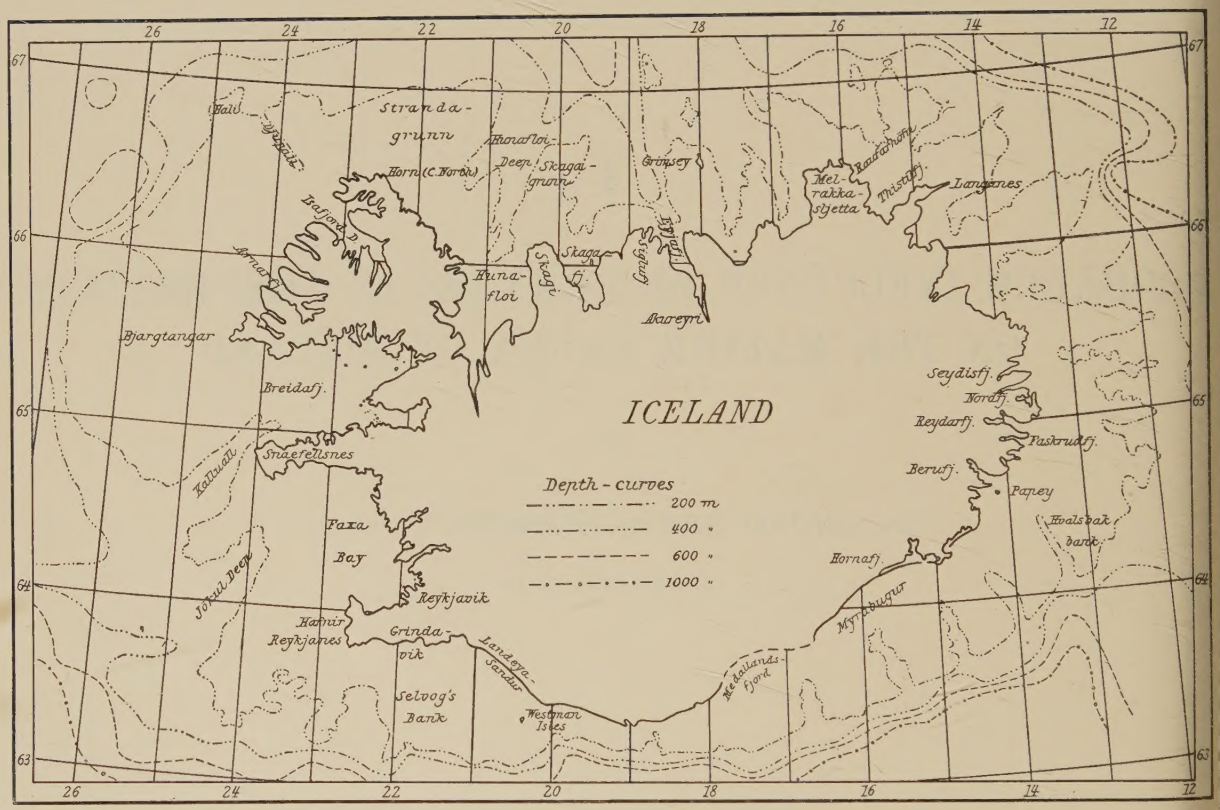
I

ROBABLE INFLUENCE OF CHANGES IN TEMPERATURE ON THE MARINE FAUNA OF ICELAND

BY

DR. BJARNI SAEMUNDSSON, REYKJAVÍK

NOVEMBER, 1932



Iceland with surrounding grounds and localities referred to in the text.

t is a well-known fact, that, during the last decen- nium or even a little earlier, the conditions in the orwegian Sea and in the waters round South-Green- nd and Iceland have altered considerably there being uch less ice than usual[1]). As far as Iceland is con- rned, the Polar ice or drift ice visits the waters off e coasts facing the Arctic Sea (i. e. the N.W-, N.- and .-coast) every few years. These waters are under the fluence of the Polar current which often makes vigation impossible by blocking the coasts for a orter or longer time. During the above mentioned riod the ice has been practically absent again, as has appeared at a considerable distance only from e coasts, the year of 1929 excepted, when during ly and August it filled the outer part of the Húna- i Bay without, however, causing serious trouble to ade, and in February—March last when an abun- nce of ice appeared off the NW.- and the N.-coast thout impeding harm to the navigation.

Simultaneous with this scarcity of ice in the waters und Iceland the winters have been exceedingly mild, pecially during February and March, when the mean mperature was some 4 to 7° C. above normal - 2.5°)[2]). The mildness of the winters during these ars might certainly be regarded as a consequence the absence of Polar ice, but another factor is of ll greater importance: namely the higher tempera- re of the sea round Iceland and of the adjacent tic waters[3]), and this factor cannot be left out of nsideration, as together with the prevalent south- ly winds during this period, it must be counted the mary cause of the high winter temperatures in eland and of the great scantity of ice in these rthern waters.

As recorded in the Naut. meteorol. Annual of the n. Meteorol. Institute for the years 1921—1931 d in the "Veðráttan", the Annual of the Icel. teorol. Office for the years 1926—1931, the surface- mperature of the sea at various places round Ice- d has, as a rule, proved considerably higher, ring these years, than during the precedent decades. is increase of the surface-temperature has amounted about 0.5—4.0° above the normal, being higher on the E.- and N.E.-coast, lower on the S.- and W.-coast, and like the temperature of the air, that of the sea has some years been relatively highest during the months of February and March. In the "Veðráttan" the following figures are given for the last six years:

1926	1927	1928
1.0 E.[1])	1.3 E.	1.7 E.
0.3 W.	0.6 W.	1.2 W.
1929	**1930**	**1931**
2.3 E.	0.3 W. & N.	1.5 N.
1.1 S. & W.	0.9 S.E.—S.	0.6 S.E. & S.

and these numbers give a fair idea of the increase that must be considered due to a stronger than usual Irminger current.

A passage from a letter which I received from a fisherman at Raufarhöfn, N.E.-Iceland, dated March 25, will give a fair illustration of the surface temperature during the winter months of 1929. It runs as follows: "This winter the temperature of the sea has never been below + 3° C., but as a rule 4°—5° and a few times even more." The normal surface temperature in this tract (Thistilfjord) in the months of December—February is about 1°—1.5° C. and in March —April about 0°—1° C., the increase has thus been as much as 3°—4° or even more.

Another example illustrating the increase of temperature in 1926, one of the warmest years during this period, can be quoted from the measurings on board the "Dana" off the North-coast where she was engaged in research work during the month of July. At various stations between Skagagrunn and Melrakkasljetta she measured surface temperatures of 10°—12° C., or 3°—4° above normal, recorded only once before (July 1908, Naut. meteorol. Ann.). This high temperature was not confined to the surface only; at 200 m. depth it proved to be 5°—6° and at 400 m. (the greatest depth measured) even over 4.5°. The highest surface temperatures, about 12° C., were measured farthest East, near Melrakkasljetta. Generally speaking the temperature in these tracts was very much the same as that at similar depths off the S.- and S.W.-coast of the country, where the water is generally warmer than elsewhere on the coasts of Iceland.

I shall conclude by quoting, as an example, the temperature measured by the "Dana" in deep water off Eyjafjord (66° 24′ N., 18°50′ W.) on July 7th 1926, as compared with those measured by her at the same station on July 20th 1924.

) Cfr. the Nautical-meteorological Annual (Nautisk me- rologisk Aarbog) of the Danish Meteorological Institute, penhagen, 1897—1931.

) Cfr. Veðráttan, Meteorol. Annual of the Meteorological ce, Reykjavik, 1926—1931.

) Cfr. Ad. S. Jensen og Paul M. Hansen: Investiga- ns on the Greenland cod. Rapp. et Proc. Verb. Vol. XII. Scientif. Rept. of the N.W.-Area Comm. for 8—1929. I. Copenhagen 1931.

. Knipowitsch: Rasche Veränderungen . . . im Barents r. Bull. de la Comm. pour l'étude de Quaternaire, No. 3.

[1]) The capital letters indicate the East-, North-, West-, South- and South-east Coast respectively.

The figures are:

	July 7th 1926[1])	July 20th 1924[2])
Surface	10.74° C.	7.27° C.
100 m.	5.81° -	5.06° -
200 -	5.03° -	4.12° -
300 -	4.91° -	2.73° -
400 -	4.62° -	0.47° -

The difference is striking, especially in deep water, 300 m. and more. The temperatures in 1924 can be regarded as normal for these tracts. Ten days later the temperature at the first recorded station had diminished so much as to be nearly normal, but further east, all round the N.E.-corner of the country, the high temperature remained fairly steady; on this same trip of Aug. 2nd we thus measured 8.34° in the surface and 4.93° at 80 m. off Seydisfjord some few miles only north of the spot where I measured a surface-temperature of 5.2° C. on Aug. 1st 1930.

After these introductory remarks, mainly concerning the temperature during the above mentioned warm period, I shall give some information about its apparent biological influence, like on some of the higher animals, mainly the fishes, belonging to the fauna of Iceland and that of the surrounding waters as well as of other northern waters.

Amongst the common Icelandic fishes, affected by this change of temperature, I shall first mention the Cod, (*Gadus callarias* L.), the proper "fish" of the Icelanders[3]). The great fishery, based upon the spawning of this fish, is generally carried out along the S.- and S.W.-coast, during the early spring (March—May), while this period is mostly a dead one on the opposite coasts, i. e. the N.- and N.E.-coast. During most of the "warm" years after 1924, great shoals of mature cod have met during the spawning period off the N.- and N.E.-coast, e. g. off Siglufjord, at Grimsey and in Thistilfjord, resulting in big catches of cod. According to statements, made by the fishermen, many of these cods were mature with fully developed milt and roe, and have probably spawned there, although no results of spawning, such as pelagic eggs or fry, have afterward been found.

In spite of this new gathering of spawners on the N.- and N.E.-coast, shoals on the ordinary spawning grounds along the S.- and S.W.-coast of the country had in no way diminished (*vide infra*).

Possibly the transport of pelagic cod fry from Iceland to Greenland by the western branch of the Irminger current, as observed by the "Dana" in 1931 and 1932, is due to the fact, that this branch has lately become stronger[4]).

Another very common fish at Iceland, which has apparently been affected by the change in temperature is the Capelan (*Mallotus villosus*, O. F. Müller). This little, sub-arctic marine Salmonid used to visit the S.- and S.W.-coast almost every year in March—May, spawning in lagoons and estuaries, or in the quite shallow waters practically on the very beach, where it finds the right temperature (about 6° C.) necessary for hatching its eggs. On the more northerly and easterly coasts it spawns later, in May—July[1]). During the last four years of this period, or more correctly since 1928, the capelan has been very scarce or totally absent on the spawning places on the S.- and S.W.-coast, except in the lagoon of Hornafjord, where — fortunately for the local fishermen who catch it in large quantities and use it as bait for the cod — it has never been lacking. Simultaneously with this absence of the capelan in spring on the S.- and S.W.-coast, it has appeared in great numbers on the N.-coast (Siglufjord, Eyjafjord) earlier than before. According to my opinion these facts are due to the unusually high temperatures in these tracts, thus rendering it unnecessary for this sub-arctic fish, which finds its food mainly in the cold waters of the Norwegian Sea, to go as far south as before in order to find suitable spawning conditions. A similar northward movement of the capelan has been observed during these years along the S.W.- and W.-coast of Greenland[2]).

It is a well-known fact, that the capelan is the favourite food of the cod, on which it occasionally gorges lavishly. — Simultaneously with the above mentioned shortage of capelan on the S.- and S.W.-coast, the cod has been uncommonly, and even (1929) extremely, lean; the cause of this being either the lack of the valuable food represented by the capelan or the enormous number of the cod itself which in these particular years has visited the spawning areas of the S.- and S.W.-coast without finding sufficient food during the forageing season.

As briefly sketched by the author (op. cit., p. 45) the Icelandic Herring (*Clupea harengus* L.) consists of two distinct races, a spring-spawning and a summer-spawning one, but unfortunately nothing is known with certainty about the extent of their spawning areas. Probably that of the first-mentioned is confined to the S.- and S.W.-coast while hitherto the latter has been known to spawn along the S.W.- and S.-coast, between Snaefellsnes and the Westman Isles, and probably even farther east. In the particularly "warm" year 1926, however, the author was able to ascertain that, in July, a considerable spawning had

[1]) Bulletin Hydrographique 1926.
[2]) ibid. 1924, p. 46.
[3]) Cfr. the Author: Synopsis etc., p. 41.
[4]) Cfr. the Author: Synopsis of the Fishes of Iceland. Rit Visindafjelags Íslendinga II. Reykjavik 1927, p. 24.

[1]) Re. migrations of the grown-up Cod between Iceland and Greenland: see Johs. Schmidt: Summary of the Danish marking experiments etc., Rapp. et Proc. Verb. des Reunions, Vol. LXXII. Scientific Rept. of the North-Western Area Committee for 1928—1929, III. Copenhague 1931, and re the currents in the Denmark Strait: see Å.V. Täning: Driftbottle Experiments in Icel. waters. Op. cit., Same Vol. V.
[2]) Cfr. Ad. S. Jensen and Paul M. Hansen op. cit., p. 39—40.

ken place as far north as the bay of Reydarfjord
the E.-coast and in August 1929 he found plenty
spawning herring in Isafjord Deep on the N.W.-
ast. Nothing being formerly known about spawning
rring in these regions — so remote from the main
awning grounds — I consider it probable that both
ese facts are due to a temperature in the sea, higher
an usual. Whether any further spawning has taken
ace in these parts I can not tell; at least, people on
e E.-coast know nothing about any recurrence there.

The probable influence of a higher temperature on
e life of the three common fishes, the Cod, the
pelan and the Herring, which I have mentioned
ove, also seems to have been extended to some
er types of fish and to such fishes as can be con-
ered stragglers only in Icelandic waters. Some
explanatory examples will suffice.
Before this period the Witch (*Pleuronectes cyno-
ssus* L.) was not known to live off the N.-coast, the
thern limits of its horizontal distribution being
Djupall off Isafjord Deep. In May 1926, some few
ng and grown-up specimens were caught by the
wler "Skallagrimur" on the outer edge of Stranda-
nn (240—250 m.), some 40 miles N.E. of Horn
pe North) and during the same month, 1931,
ee more specimens were caught by the same
wler on the west-edge of the Skagagrunn (about
m.) which forms the eastern limit of the Húnaflói
p. In my opinion, the extended horizontal distribu-
of this fish into more northern and colder water
ue to the increase of temperature.
ne of the rarer fishes in shallow waters off Iceland
he Turbot (*Rhombus maximus* L.), which is
sionally caught in trawl or on long line but off
western part of the S.-coast and in the Faxe Bay
. Last winter I had a grown-up specimen from the
t-coast, caught in a Danish seine off Faskrudsfjord
November 6th, 1931. I imagine that the appearance
ne Turbot here is due to a temperature higher than
l in those cold waters, all the more so, as there
other instances proving that fishes of a more
lhern origin have visited this coast during the
years.
ne of the Fishes in question is the Basking
rk (*Selache maxima* (Gunn.)). This gigantic
choid, the home of which in the N.-Atlantic is
to about 35° N. lat., is a rather frequent
mer-visitor in the tracts along the S.- and
ast, though very rare on the N.-coast and
the cold water off the E. and N.E-coast it has
r been known to appear prior to 1926, when
Nordfjord-fishermen, returning from a fishing
on August 9th, told the author that they had
rved, off Seydisfjord, a creature that according
eir description must have been a basking shark.
winter one specimen was killed in Berufjord on
S.E.-coast, about March 10th[1]). Its liver filled
l. — These two cases when the basking shark

The mean temp. for Febr. was 2.7° above normal at
.

appeared in the cold water on the S.E.- and E.-coast are — according to my opinion — due to a higher temperature during this period, than is otherwise usual.

The second of these fishes is the Tunny (*Orcynus thynnus* (L.)). It is decidedly less common at Iceland than the basking shark; prior to 1927 only some 10 specimens are recorded[1]) and, with one exception only, these are all from the S.- and S.W.-coast. — At the end of July 1928 one grown-up (250 cm. long) specimen was washed ashore on the S.-coast (Landeyjasandur) and during the first half of August 1929, there was, I am told, a great number of them all along the southern part of the E.-coast where its occurrence was never recorded before. People in the town of Nordfjord tried to kill some which visited the fjord by shooting but without success. — Almost simultaneously a little shoal of tunnies is reported to have appeared in the innermost ramifications of Arnarfjord on the N.W.-peninsula, probably attracted by great shoals of herring or Cuttlefish (*Ommatostrephes*). None of them were caught. — In July 1931, one specimen had become entangled in a herring-net at the Westman Isles but succeeded in extricating itself with the loss of some scales of which the author got two large ones. Also finally four full-grown specimens, one fresh and unhurt and three badly injured (by seals or killer whales?), drifted ashore in Myrabugur on the S.E.-coast in August last. These records indicate a veritable influx of the Tunnyfish into Icelandic waters, as compared to the dispersed occurrences in former days, corresponding with what happened in the waters of Denmark and Norway during the same period and is undoubtedly here — as there — due to the higher temperature in the sea, especially off the E.-coast.

The Mackerel (*Scomber scombrus* L.), as a rule, is a frequent summer-visitor in the bays of Iceland though with a few exceptions only, as single specimens[2]); but in 1928 a good many were caught in a purse seine in the bay of Skagafjord (N.-coast), 8 specimens in herring-nets in the Eyjafjord (N.-coast) in September 1929, and, in the summer of 1930, a great number (some barrels) are reported to have been caught in one haul by a herring seine in Mjoafjord (E.-coast). Beside these cases many single specimens have been caught by the herring-fishers in different places off the W.- and N.W.-coast during the same years. — I suppose, that the increased appearance of this fish, especially on the E.-coast where it is otherwise very rare, is mainly due to a higher temperature in the sea.

The Skipper (*Scombresox saurus* Walb.) is one of the southern summer-visitors to the coasts of Iceland, but it is not numerous, and only 16 specimens are recorded as being washed ashore before 1927[3]) on the greater part on the S.- and W.-coast; one only on the E.-coast. During the last five years 7 specimens are recorded, 5 on the S.W.- and W.-coast, 1 on the

[1]) Cfr. the Author: Synopsis etc., p. 15.
[2]) Cfr. the Author's op. cit., p. 14.
[3]) Cfr. the Author's op. cit., p. 38.

N.- and 1 on the E.-coast. This is a remarkable increase in their appearance and is probably due to the higher temperature.

The Sunfish (*Orthagoriscus mola* L.) is one of the rarest stragglers in Icelandic waters, as but 5 or 6 adult specimens are recorded before 1927, 2 on the N.-, 3 or 4 on the S.- and S.W.-coast. Since that year, 2 more specimens have drifted ashore on the S.-coast, one adult on Landeyjasandur in August 1928, and a young one, only 31 cm. long, in Grindavik at the end of November 1931. — Perhaps the appearance of these two cases, especially the latter one, just in this warm period, is caused by the influence of water warmer than usual.

One of the rare fishes in Icelandic waters is the Scopelid (or Sudid) (*Paralepis Krøyeri* Lth.) which is recorded twice only before 1927, one specimen each time[1]). On a trip in the trawler "Skallagrimur" to the edge of the fishing grounds (Hvalsbak Bank) off the S.E.-coast, in May 1930, however, the author found plenty of stomachs of the Coalfish (*Gadus Virens* L.) and some few of those of the cod stuffed with young (immature) specimens of this fish, the habitat of which must be somewhere south in the Atlantic[2]), towards the Azores, and from here the young ones successively migrate northward sometimes right up to the S.-coast of Iceland. And, as I know of no such earlier mass-appearances of this fish I should imagine that it was due to the same cirstumstances as concern others of these fishes.

As to the influence of the higher temperature of the sea on the migrations of whales in the waters round Iceland during this period I can give no information beyond mentioning that, in the summer of 1926, a good many Whalebone Whales, Sei-Whales (*Balænoptera borealis* Less.) as far as I could ascertain, were observed by the author off Hafnir on the W.-coast of the Reykjanes-peninsula about the middle of August and by fishermen some days earlier off Grindavik on the S.-coast of this peninsula. Although recently bigger whalebone-whales have probably increased in number in Icelandic waters owing to their being protected this relatively large number of a southern whale is still extraordinary and may be looked upon as a consequence of the general increase in temperature.

From these scanty reports concerning the habits of certain vertebrates in Icelandic waters during the last ten years or so, with increased temperature in sea and air, I cannot but draw the conclusion that generally speaking it has driven them northward. But unfortunately I cannot tell what its influence may have been on the lower (invertebrated) animals because neither have I had the opportunity to make a thorough investigation of this question, nor is my knowledge of the horizontal distribution along the coast of Iceland as concerns plancton and benthos sufficient to allow me to form any reliable conclusions as to a possible influence upon them. I will only mention that during my trip onboard the "Skallagrimur" to the fishing grounds off the N.-coast in 1931, I found on the Skagagrunn one specimen of the large Sea-urchin (*Echinus esculentus* L.) and a young one of the well-known Polychæte, the Sea-mouse (*Aphrodite aculeata* L.). As far as I can ascertain, only the first-mentioned had been found previously along the S.- and S.W.-coast, from Medallandssjór to Isafjord Djup[1]), and the second only at the S.- and S.W.-coast (Westman Isles—Faxa-Bay). Possibly the appearance of these two warm-water-animals in the usually cooler waters off the N.-coast, so remote from their usual habitat, is due to the augmented temperature of the water in these tracts.

In addition to the information given above, concerning the marine fauna, I should like to mention that the unusually warm climate, especially the mild winters, in Iceland, predominant during the period in question, seems to have attracted some marine birds from the neighbouring countries, and has made them immigrate into this country where they have found conditions favourable enough for nesting and breeding. Of such birds I can mention three species of common North-European gulls: 1) the Black-headed Gull (*Larus ridibundus* L.) which is now quite common in the vicinity of the capital, both fullgrown and young, which are also well-known in many other places in the North and the South of the country during the last years, after a few years' absence; previous to that period it was pretty rare or quite unknown[2]). 2) The second species is the Lesser black-backed Gull (*Larus fuscus* L.), first observed in Iceland 1905 (Hørring), after 1920 fairly common on the S.-coast, e. g. at the Westman Isles often seen in the harbour of the capital and probably nests somewhere on the S.-coast. 3) Of the third species, the Herring Gull (*L. argentatus* Brünn), the first specimen was observed on the N.-coast in 1909 (Dinesen). Of later years it is not rare on the E.- and the S.- and S.W.-coast and probably nests on the E.-coast at least[3]). — During the same period the arctic species, the Ivory Gull (*L. eburneus* Phipps.) formerly a rare winter-visitor, even on the S.W.-coast has never been observed.

Finally I can record that one terrestic bird, comparatively rare in Iceland, the Shortеared Owl (*Otus brachyotus* Forster), has nested and bred every year with good results in several places in S.W.-Iceland during later years, favoured perhaps by the great field-mouse-year of 1928.

[1]) Cfr. the Author, Synopsis etc., p. 44.

[2]) Vilh. Ege, Sudidæ (Paralepis), Rpt. on the Danish Oceanogr. Expeditions 1908—1909 etc., Vol. II. Biology No. 10, A. 13. Copenhagen 1931, p. 17 and 106.

[1]) Cfr. the Author: Bidrag til Kundskaben om Islands polychæte Børsteorme. Vid. Medd. fra Nat. Foren. i København, Bd. 69, S. 179.

[2]) Cfr. the Author: Zoologiske Meddelelser fra Island XIII. Vid. Medd. fra Nat. Foren. i København, Bd. 65, S. 4[illegible]

[3]) Cfr. Á. V. Tåning: Sølvmaagen (*Larus a. argentatus* Pontopp.) ny for Island. Dansk ornithol. Foren. Tidsskr. XXII, København 1928, S. 91—96.

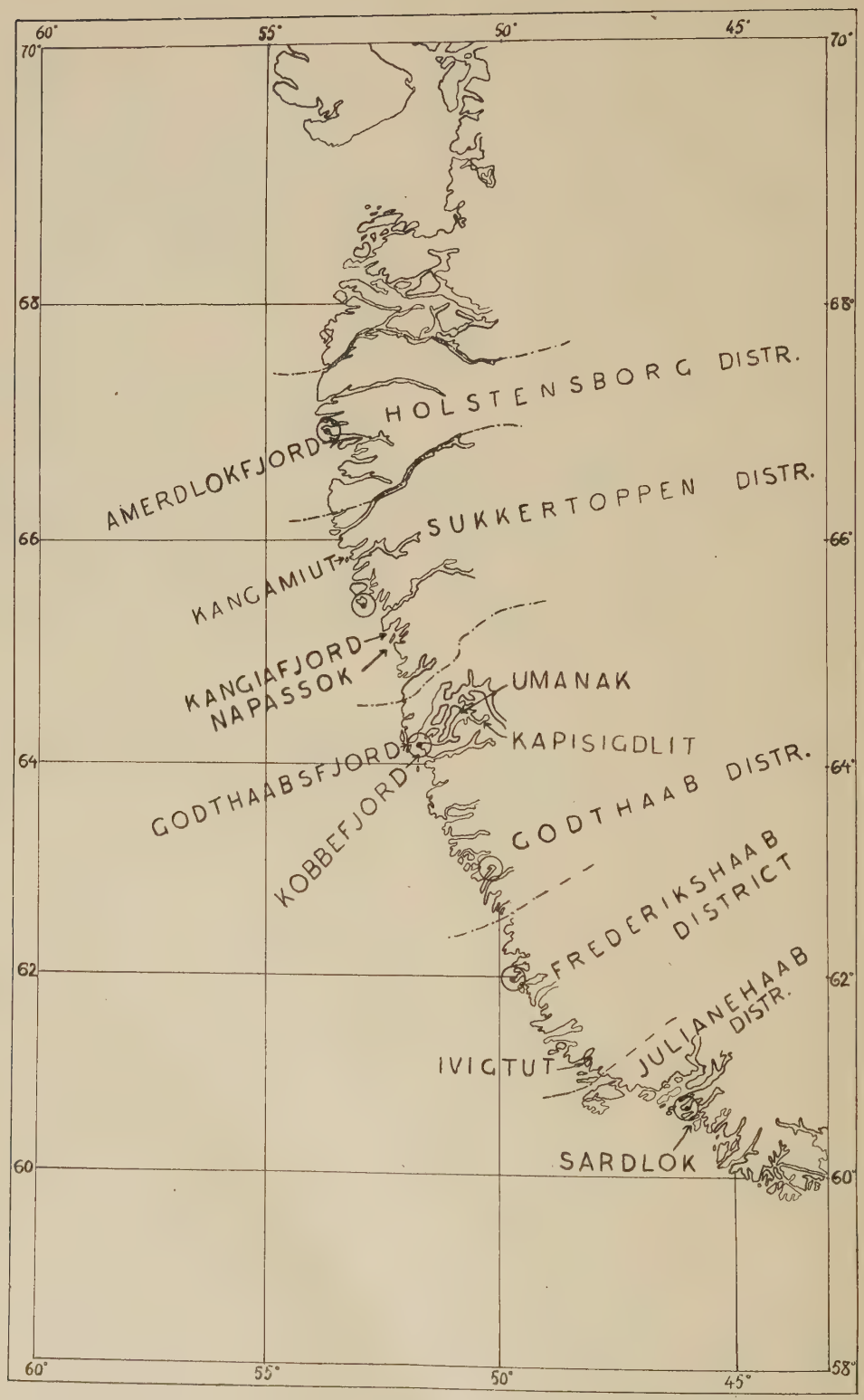
II

NOPSIS OF INVESTIGATIONS INTO FLUCTUATIONS IN IE STOCK OF COD AT GREENLAND DURING THE YEARS 1930—1933

BY

PAUL M. HANSEN

ASSISTANT TO THE FISHERIES INVESTIGATIONS
OF THE GREENLAND DIRECTORATE



Survey chart, showing localities and districts referred to in the report.

these our investigations into fluctuations in the tock of cod at Greenland an endeavour has n made to carry through the researches by means ge-determinations of a great number of cod from various districts.

he material has been collected, to some extent, he managers of the fishing stations at Holstens- and Sukkertoppen, but the bulk of it has been ided by the M/B "Umarissok", which was placed ur disposal by "Grønlands Styrelse" for fishery rches in the fjords and along the West coast of nland.

has been our aim to determine the proportion e appearance of each year-class in the catch and ariations of these from year to year at the various ities along the S.W. coast; we have therefore avoured to make the collected material as re- ntative as possible and the fishing has con- ently been carried out at various depths, by means ndline as well as longline, with a view to securing rge a number of samples as possible.

is not, however, feasible to give an absolutely ct picture of the composition of the cod stock eans of the gears used as these are apt to leave certain size-groups. Thus, longline samples ally show a greater number of the older year- es than do handline samples.

e-determinations have been made from otoliths sively. Scales have not been used as the deter- tion proved extremely uncertain, the winter- of the outer edge not being distinctly separated. he other hand, winter-rings of otoliths are de- y distinguishable and easy to count with great acy right up to the age of 15—16 years. Even mens of 21 years were usually easy to count. ch single cod, from which otoliths were taken, measured and its sex determined. The number nter-rings of otoliths were read through a bin- r lens magnifying 20 times. The otolith was n in the middle. In some cases the surface was d but as a rule grinding was unnecessary. g the examination, the otolith was held by rs immersed in spirit and strongly illuminated ect light.

Districts and Material.

facilitate the general survey, determinations arious localities have been grouped in districts[1]). ling the material in this way (i.e. by districts) does not necessarily give the most natural division as the widely extended districts are divided by administrative boundaries only. Thus, the sample from the Sukkertoppen district (1933), which was taken at Kangamiut in the northern part of the district, should possibly be compared with the Holstensborg samples, an assumption which is particularly supported by the resemblance in the 1917- and 1922-groups.

No material is available from the northern districts such as Egedesminde, Disco and Umanak and the presence of cod, therefore, has not been discussed in this report.

Unfortunately, it has not been possible to make investigations in all districts every year. Thus, in 1930 no material is at hand from Sukkertoppen, neither in 1931 from Frederikshaab nor from Julianehaab in 1933.

Off the east coast material is available from the Angmagssalik district for 1931 and 1933. That of 1933 has been collected by a Danish student, Mr. BERTHELSEN, member of the 7th Thule-expedition, but

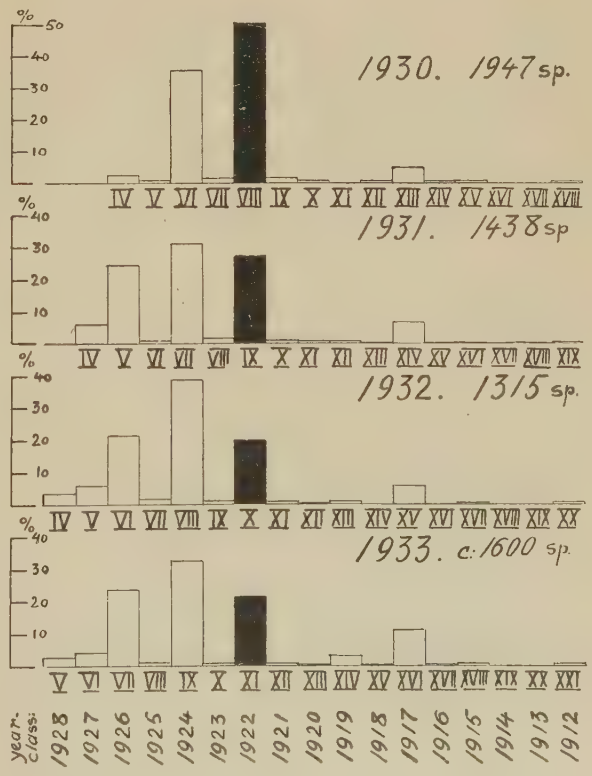


Fig. 1. Age distribution of total catches. SW. Greenland coast.

[1]) e chart on p. 2 (1) with names referred to in this The chart also shows the boundaries between ts.

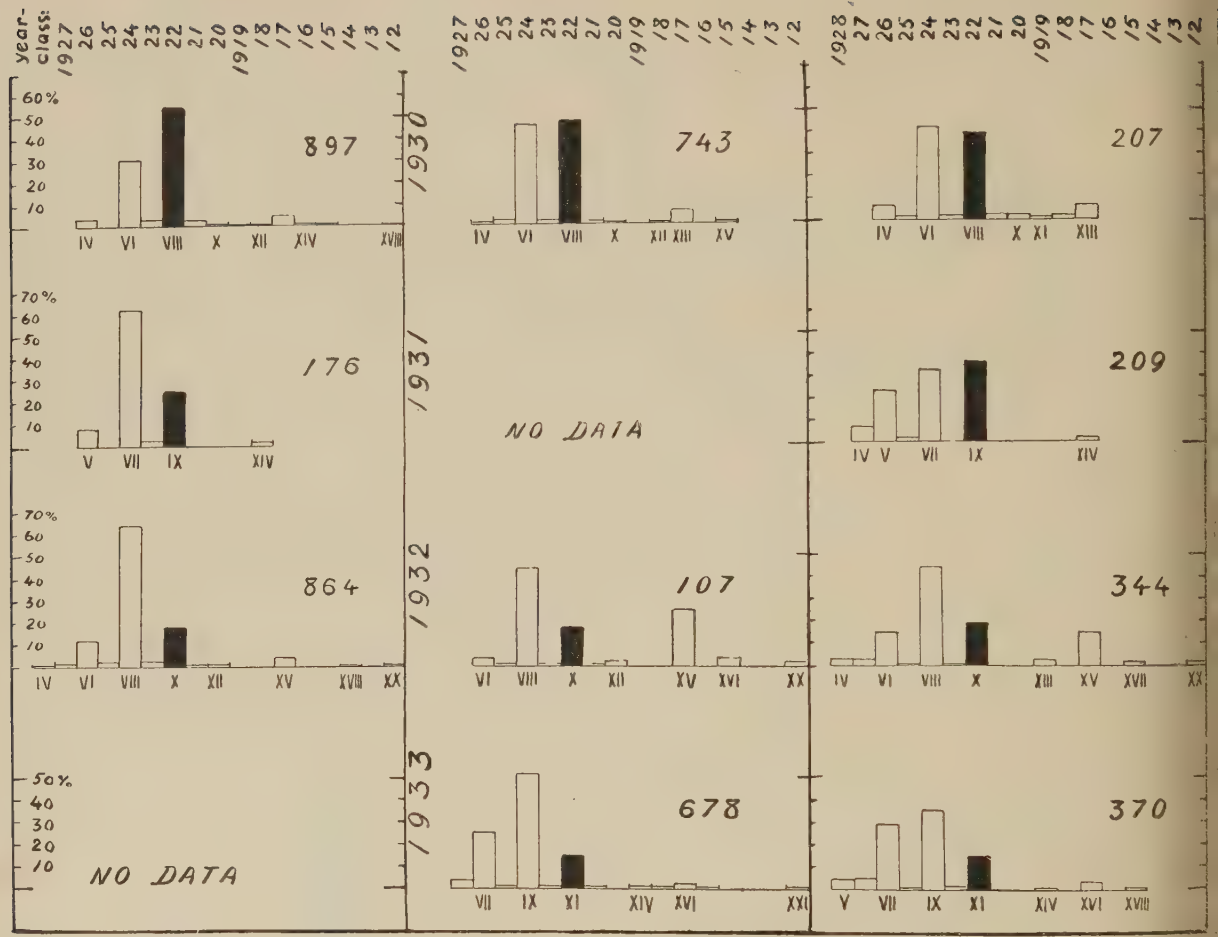


Fig. 2 a. JULIANEHAAB FREDERIKSHAAB GODTHAAB DISTRICT

comprises no more than 55 specimens. (In the following a (!) next to percentages indicates that the figure refers to this very small sample.)

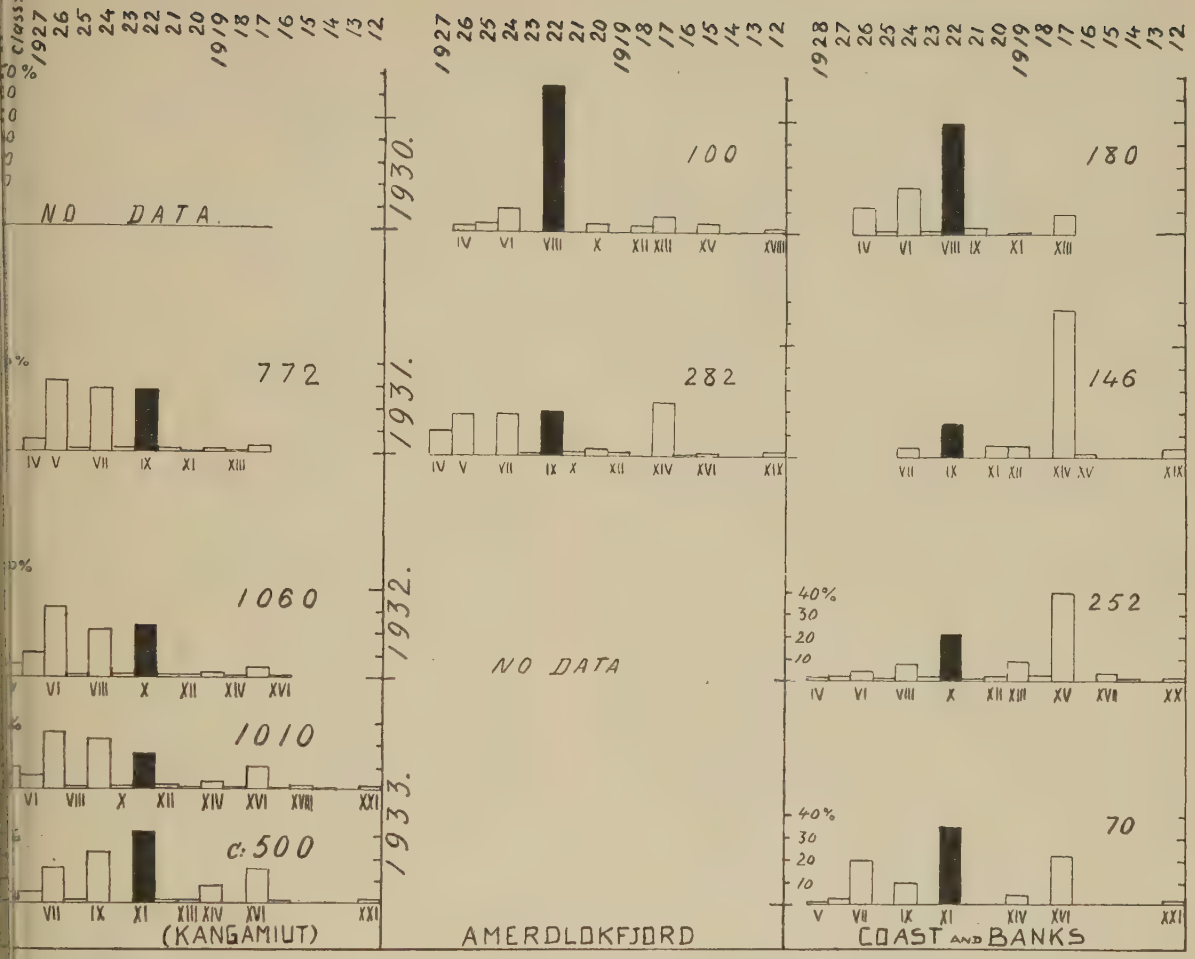
The material from the Holstensborg district, from the fjords as well as from the coast, was collected in 1930 partly by Greenlanders and probably it is not made sufficiently representative. It does not agree with other samples from this locality and, probably, it ought not to be taken into account.

As regards the number of determinations from the several localities it should be said that in most districts they count above 200, a number which experience has shown to be sufficiently high to give results as exact as required. Comparisons between smaller samples (about 100) from neighbouring localities within the same districts have shown very close agreement between the observations.

Analyses of this kind have been continued at W. Greenland since 1924 and earlier results were reported in the N.W. Area Report of 1931 (Rapp. et Proc.-Verb. Vol. LXXII). These investigations proved that certain year-classes were absolutely dominating while others could hardly be traced. In 1924 and 1925 the year-class 1912 dominated on the banks while in 1924 the year-class 1917 was the most prominent. Since 1926 the year-class 1922 has predominated in the coastal catches and in 1929 the year class 1924 began to assert itself. The year-classes 1918, 1919, 1920, 1921, 1923 and 1925, have been very scarce everywhere.

When studying the general survey of the S.W. Greenland coast for the years 1930—33 (Fig. 1) it becomes obvious that, as before, a few year-classes predominate while others are quite insignificant. The year-classes 1922, 1924 and 1926 are those that dominate during all four years, but also the year-class 1917 asserts itself in spite of its high age.

In the following a survey is given of the appearance of the various year-classes at W. Greenland as well as at Angmagssalik on the east coast.



SUKKERTOPPEN HOLSTENSBORG DISTRICT

Fig. 2 b.

The year-classes 1912 and 1917.

The year-class 1912 is the oldest one traced in the ...nes during the four years in question. Nowhere, ...ever, more than a few specimens have been caught ... being of no special interest to the fishery. It ... caught most frequently in the Holstensborg ...ict but even there it did not represent more ... 2 to 3 % of the total catch. During 1924 and 1925 ...s numerous on the banks. This scarcity is pro... due to its having passed the maximum age ...od at Greenland so that but a few surviving ...mens of this, previously dominating, year-class, ... left in these waters.

...e year-class 1917 has appeared fairly constantly, ...ng 5 to 11 % of the total catches. — As regards ...several districts it has appeared in greatest ...bers in the Holstensborg district where in 1931 ... 1932 it dominated with 66.4 % and 39.6 % ...ctively. (As mentioned above the year 1930 cannot come into consideration). In 1933 it was outnumbered by the year-class 1922 but still retained a percentage of 23.

In the Sukkertoppen district it is rather strong in the samples from Kangamiut (14 %) and Sukkertoppen proper (10.5 %) in 1933 but, as already said, most likely the Kangamiut sample should be considered as belonging to the Holstensborg district.

In the Godthaab district it is important in the samples from 1932 and on the spawning grounds in the Godthaabsfjord during 1933. (The 1932 sample was taken in the Godthaabsfjord but after the spawning season). It represents 15.2 % and 17.6 % respectively and it is thus almost as frequent as the year-class 1922. This frequent appearance was to be expected as this spawning ground is one frequented by the older cod in preference to the coast.

At the coastal stations south of Holstensborg it has generally been comparatively scarce but for one minor sample taken in the Frederikshaab district

in 1931 where it was represented by no less than 25.2 %.

This year-class did not appear in the samples from Angmagssalik in 1931 and 1933 (Fig. 4A and B).

The year-class 1922.

The year-class 1922 has been the most important one at Greenland and has caused a considerably increased fishing since 1926 but is now decreasing: from 50.6 % in 1930 to 21.2 % in 1932. The decrease has been very sudden; in 1931 the percentage dropped to 27.3 from 50.6 during the previous year. The reason for this is, most likely, due to the extensive emigration to Iceland proved in 1931 by marking experiments.

Very likely the major part of this year-class matured in 1931 at the age of nine years and increased emigration has, therefore, taken place to the Icelandic spawning grounds.

That the decrease in numbers should form a scale for the extent of spawning migrations is not probable as markings at Iceland have proved that cod also migrate from Iceland to Greenland. It is possible that this cod is Greenland cod returning to Greenland after spawning, but marking experiments have not proved this as re-marking of marked Greenland cod has not been practicable. The probability exists that it is not all the emigrating cod that disappear from the Greenland stock, and that a certain number may return but the sudden decrease of the year-class 1922 at the age of eight—nine years seems to indicate that a great proportion of the emigrated cod remains in Icelandic waters.

The heaviest decrease of this year-class was noted in the Julianehaab district in 1931. In 1932 the decrease was but a small one.

No material was collected in the Frederikshaab district in 1931 and it is, therefore, impossible to say whether the decrease, proved in 1932, had begun during the previous year.

In the Godthaab district hardly any decrease took place from 1930 to 1931. In 1931, 1932 and 1933 the percentages were 36.3, 18.9 and 13.8 respectively (as to spawning grounds, see Fig. 3A and 7).

Unfortunately, no material is available from 1929 and therefore no opinion can be given on changes from 1929 to 1930.

From the Sukkertoppen district no material is available from 1930, but from 1929 to 1931 the percentage dropped from 60 % to 28 %, 1932, 22.4 % and 1933, 15.5 %.

In 1933 the Kangamiut sample (which probably should be considered with the Holstensborg data) shows 31 %.

The heavy decrease shown in the Holstensborg district from 1930—1931 is most likely incorrect, and, for reasons already mentioned, the material for 1930 should, therefore, not be considered.

From Angmagssalik on the east coast figure 4A shows that the year-class 1922 was represented by 22.7 % in 1931 and by 18.2 % (!) in 1933, Fig. 4B.

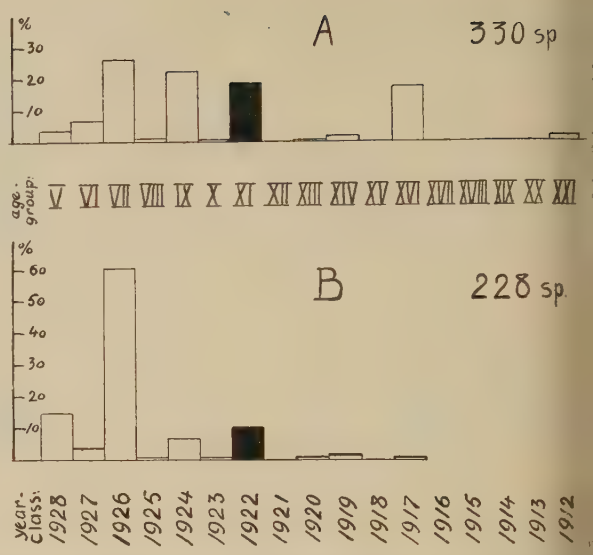


Fig. 3. A. Godthaabsfjord (spawning ground) 1933. Mai 24th to June 3rd. B. Kangiafjord at Napassok (Sukkertoppen District) Sept., 1933.

The year-class 1924.

The 1924 year-class which was represented in 1929 by some 18 % in the catches of the Sukkertoppen as well as of Julianehaab districts, shows an increase in 1930 to 35.5 % and keeps up this position during the following three years, i.e. between 30 % and 40 %. This year-class was noted quite as frequently as the II- and III-groups in 1926 and 1927 particularly so in the Sukkertoppen district.

The most natural explanation to this increase during 1930 is, that the individuals, as the VI-group, have reached a size which makes it catchable and marketable. Being previously caught as young cod at Greenland there is no reason to believe that any immigration should have taken place from other waters, nor are there any indications of migrations to any extent prior to maturity at the age of seven to nine years.

Its proportions remained fairly constant in the catches in the Frederikshaab, Godthaab and Sukkertoppen districts while in the Julianehaab district the percentage was growing from about 18 % in 1929 to 30 % in 1930, and amounted to about 62 % in 1931 and 1932. This heavy increase is obviously due to the emigration of the 1922 year-class.

Along the coast the year-class 1924 has been of the greatest importance in the Julianehaab district while northwards its importance has been gradually decreasing, being smallest in the Holstensborg district.

At Angmagssalik on the east coast it was by far the most important year-class in 1931 (55.1 %), while in 1933 it was as high as 32.7 %(!).

Our experience of the 1922 year-class which decreased heavily in 1931, viz. as nine years old, made us expect a similar emigration for the 1924 year-class in 1933, but this has not been the case inasmuch

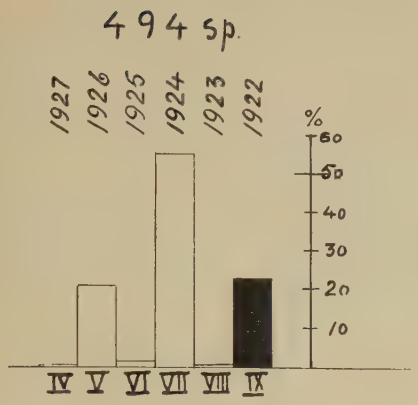


Fig. 4 A. Angmagssalik 1931.

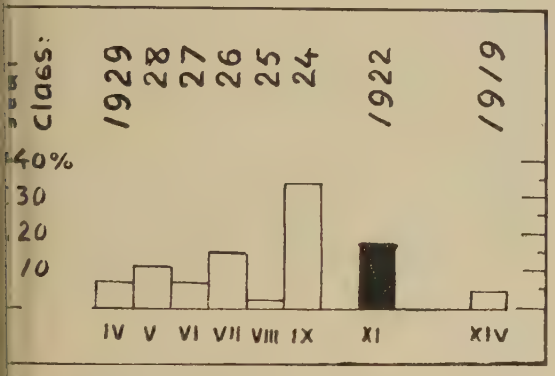


Fig. 4 B. Angmagsalik 1933. 55 specimens.

n all districts it was almost as numerous as in 2. The reason for this is not easily explained, but may presume that the greater part of this class not reached maturity at the age of nine years, lid the 1922 year-class, but that maturity may e been reached in 1934 and that the emigration the consequent decrease in percentage of the h will therefore take place next year.

nother explanation, and a more probable one, is some of the samples were derived from migrating arriving from Iceland after spawning. This is ibly the case with samples from the Frederiks- and Godthaab districts (except the Godthaabs- i) and this assumption is strongly supported by act that practically no fishing took place in these icts in spring; the cod did not appear till medio , but then it came in great quantities and caused ry remunerative fishery. Exactly the same con- ns were noted in the Julianehaab district.

s concerns the Godthaabsfjord, the samples were cted so early (i. e. end of May, beginning of June) the question of immigration cannot come into ideration; but it is noteworthy that the per- age was nearly halved from 1932 to 1933, the samples from 1932 having also been collected in the Godthaabsfjord itself although outside the spawning period.

The year-class 1926.

This year-class was represented by 2.4 % only of the total catch in 1930 and this low percentage is undoubtedly due to the small size of the individuals. In 1931, however, the percentage increased to 24.4 %, remaining at 21.2 % and 23.5 % in 1932 and 1933 respectively. This year-class does not seem as rich as either the 1922 or the 1924 ones.

In 1931 and 1932 it appears most frequently at Sukkertoppen (31.3 %) and is very scarce at Frederikshaab (2.8 %).

Already as the I-group it appeared in great numbers at Sukkertoppen where more than 2,000 specimens were caught in one seine haul.

In the Julianehaab district it was comparatively scarce in 1930, 1931 and 1932, and from 1933, unfortunately, no material is available.

In other districts the percentage varied between 20 and 30 % in 1933. In the Frederikshaab and Holstensborg districts the sudden increase in percentage took place between 1932 and 1933 and also in the Godthaab district the increase came suddenly, between 1930 and 1931.

In the Sukkertoppen district the 1926 year-class appeared fairly constantly in the catches of 1931 and 1932 (about 31 %) while a decrease took place in 1933 (24.8 %). In the Kangamiut sample it was represented by 16 %.

The sample from the Kangiafjord near Napassok in the Sukkertoppen district shows conditions quite different from any other locality inasmuch as the 1926 year-class is predominating with about 60 %, while the 1928 year-class comes second. This locality is a peculiar one as cod does appear here throughout the year and is even found spawning there in the spring. In appearance the cod is also somewhat different to cod from other Greenland localities: The body is more plump and the head shorter than usual; the belly is heavier and of a dirty greyish-brown colour. Presumably this is a local stock which keeps within the Kangiafjord and does not migrate to any noticeable distance. Off Napassok, on the other hand, the slender, light-coloured, migrating cod appears.

At Angmagssalik on the East coast this year-class like the 1922 one was represented by some 20 % in 1931, while in 1933 it dropped to 16 %(!).

Younger year-classes.

The only year-classes of a catchable size which may appear in the catches are the 1927 and 1928 year-classes, both of which, though, have been of insignificant importance.

In the Holstensborg district (Amerdlokfjord) in 1931 and in the Sukkertoppen district in 1932 the 1927 year-class reaches as high an importance as 10 %. In 1933 the 1928 year-class reaches 15 % in

the Kangiafjord at Napassok and 10 % in the Sukkertoppen as well as the Angmagssalik districts.

Neither the 1927 nor the 1928 year-class seem to be so rich that in future they will be able to replace earlier abundant year-classes.

As regards the youngest year-classes an attempt has been made to show whether there is a possibility that any of these may in future become so rich that they will be of any great importance to the fishery. In other words we have tried to determine fluctuations in the stock of cod by investigations into year-classes amongst the young cod which are still too small to be caught by means of the commercial gears.

We know from earlier investigations that the rich year-class of 1922 was present in large numbers along the S.W. coast of Greenland as early as 1924. The same results are noted for the 1924 year-class in 1926 and 1927, and also the 1926 year-class appeared in great numbers along the coast in 1927, i. e. as the I-group.

The young cod usually keeps to certain localities where shoals usually consist of specimens of approximately the same age and size. They cannot be caught on hooks of the size ordinarily used. Eel-hand-seine is the best gear for catching these codlings but fishery along the coast with this gear is frequently handicapped by the rough, uneven sea-bottom. It is not considered possible to procure details fully representative for the determination of fluctuations of such shoals.

in the percentage contour in Fig. 5. The I-group (year-class 1931) consists of specimens 10 to 16 cm. long; the majority of the individuals measured 22—36 cm. including the II- and III-group (the year-classes 1930 and 1929 respectively). It appears from their age and size that two thirds of the catch belong to the 1930 year-class.

2688 codlings were taken in 1933 (June 16th) in one haul with eel-seine in the Kobbefjord near Godthaab. From Fig. 6 it will be seen that the majority of this catch measured from 18 to 30 cm. Their age and size proved that the specimens mostly belonged to the II-group, viz. year-class 1931, while the III-group was relatively scarce. Evidently a nursing ground for small cod exists in the Kobbefjord.

69 codlings, 16—60 cm. long, were caught in the Godthaabsfjord near the Umanak island in 1933 (June 3rd) by means of jig with small hooks; the greater part of them measured 20 to 45 cm. Age and size showed the following distribution: I-group 3; II-group: 9; III-group: 50; IV-group: 16 and V-group: 1. In contradistinction to the conditions in the Kangiafjord the 1930 year-class seems to be the most numerous one, but this may be due to the use of jig here while eel-seine was used in the Kangiafjord.

1417 codlings were taken in one haul in the Ivigtut fjord near Taylorshavn in 1933 (July 14th); all of the 695 specimens investigated measured from 10 to 17 cm. with a maximum of 14 cm. while the average

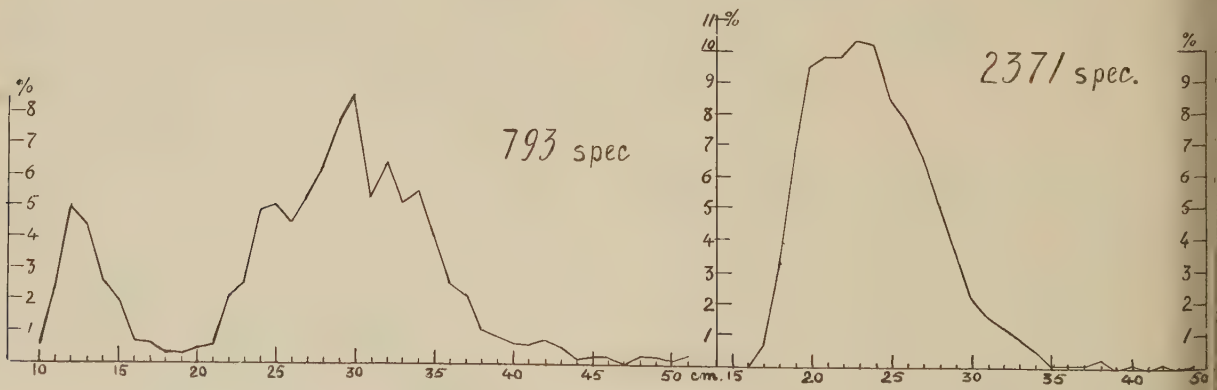


Fig. 5. Cod measured at Sardlok (Julianehaab district) Aug. 11th, 1932.

Fig. 6. Cod measured at Kobbefjord (Godthaab district) June 16th, 1933.

In several places cod of the I-group was caught in 1930 and 1931 although generally in small numbers only. In July 1931 a fairly large number of the II- and III-groups was caught in the Amerdlokfjord near Holstensborg; the most numerous one being the II-group.

The greatest catches of young cod were taken in 1932 (August 11th) at Sardlok in the Julianehaab district and in 1933 (June 16th) in the Kobbefjord in the Godthaab district. The lengths of specimens (793 individuals) in the catches in Sardlok is shown

length was 13.44 cm. The entire material bar 2 specimens of the II-group, belonged to the I-group.

It will be noticed that codlings of the 1929 year class were caught in greatest numbers in the Holstensborg district in 1931 while in 1932 and 1933 the year classes 1930 and 1931 respectively were mainly caugh in the respective districts of Julianehaab and Godthaab. Near Ivigtut it was chiefly the 1932 year-class that was caught in 1933.

The future importance of those year-classes cannot be predicted.

Racial Investigations.

Investigations into racial characteristics have been ade in 1933 from three different cod populations at W. Greenland, namely:—
in the Godthaabsfjord at Kapisigdlit (spawning ground),
in the Kobbefjord near Godthaab, and
in the Kangiafjord near Napassok (Sukkertoppen district).
The numbers of vertebrae and of rays in the second rsal fin are given below:—
1) Godthaabsfjord near Kapisigdlit. This sample nsists of big spawning cod exclusively.

t.	No.	D_2	No.
.....	1	24.....	1
.....	3	23.....	1
.....	14	22.....	17
.....	43	21.....	34
.....	53	20.....	36
.....	20	19.....	28
.....	3	18.....	13
.....	—	17.....	3
		16.....	1
al.....	137	Total.....	134

Average no. of vert.: 53.42. D_2: 19.94.

) Kobbefjord near Godthaab. This sample consists odlings of the II-group:—

	No.	D_2	No.
.....	1	25	1
.....	37	24	5
.....	102	23	19
.....	77	22	37
.....	20	21	55
.....	2	20	55
		19	13
		18	10
		17	—
		16	1
al	239	Total	196

Average no. of vert.: 53.65. D_2: 20.89.

Kangiafjord near Napassok. This sample consists iddle-sized and big cod taken at random from ce tches.

	No.	D_2	No.
.....	2	22	5
.....	24	21	14
.....	62	20	34
.....	28	19	40
.....	3	18	18
		17	4
		16	2
l	119	Total	117

Average no. of vert.: 52.95. D_2: 19.38.

A comparison between the two sets of figures, as well as with the previous racial investigations by the late Professor Johs. Schmidt[1]), will show that they run parallel. Schmidt gives the following means from the Sukkertoppen and Julianehaab districts l. c. 50—51):

Sukkertoppen		Julianehaab	
Vert.	53.39—53.85	Vert.	53.18—53.42
D_2	19.92—20.88	D_2	20.01—20.38

Schmidt's samples consist of not-spawning fish: specimens from the Sukkertoppen district were exclusively taken from the outer coast while those from Julianehaab were taken a short distance within the fjord.

Of the present samples, sample no. 1 is of special interest inasmuch as it consists exclusively of spawning fish, caught at the bottom of the fjord (see further below). The age analysis is shown in Fig. 3 A (in this not-spawning cod has been included, though); we know that cod has migrated from the offshore banks to the spawning place in this particular fjord and *vice versa*. Compared with Schmidt's figures as well as with sample 2 consisting of codlings from the coast the figures do not seem to indicate that this be a special fjord race.

Sample 3 (see also age-analysis, Fig. 3 B) originates from the bottom of the fjord far from the outer coast, and this sample shows the lowest figures known at W. Greenland; the sample consists of non-spawning cod. It should be mentioned, however, that at other seasons of the year spawning cod can be found in this locality.

It is not possible to say as yet whether those low figures express the fjord phenomenon mentioned by Schmidt or whether they are due to other causes.

Investigations into Spawning Cod in the Godthaabsfjord.

From May 24th to June 4th 1933, 330 specimens of cod from a spawning ground (Kapisigdlit) in the Godthaabsfjord were investigated. In addition to age-analyses (see Fig. 3 A) and race-analyses (already mentioned) the sexual organs of all of them were analysed as to maturity, an investigation, though, which was rather difficult in respect of the young female specimens. Several individuals showed very small ovaries of a light red colour and were apparently immature. When the ovary was opened, however, it proved to contain minor portions of fully ripe eggs. The cod in question were most likely first-time spawners. Dr. Tåning informs me that similar cases have been observed by him both at Iceland and at W. Greenland and in the case of old cod as well.

The following table gives the result of the maturity-analysis, i. e. the number of individuals of each sex

[1]) Johs. Schmidt: Racial Investigations X. C. R. Lab. Carlsberg, 18me Vol. No. 6, 1930.

and each age-group in each of the categories: 1) Immature cod, 2) mature cod expected to spawn during the season, but not yet commenced to do so, 3) spawning cod, 4) spent cod (many of which had accumulations of blood in the ovary), 5) cod with deform organs, and 6) undeterminable specimens.

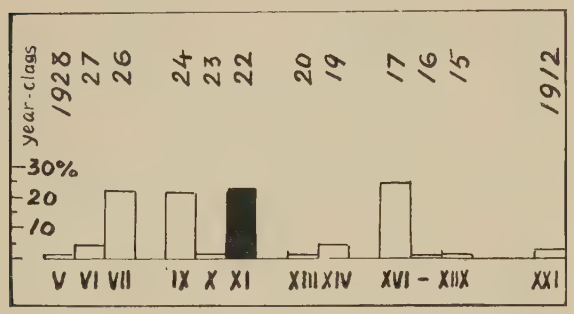


Fig. 7. Spawning cod, Godthaabsfjord, 1933.

Table A.

Year-class	Group	(1) Immature ♂	(1) Immature ♀	(2) Mature but unripes ♂	(2) Mature but unripes ♀	(3) Spawning ♂	(3) Spawning ♀	(4) Spent ♂	(4) Spent ♀	(5) Deform sexual organs ♂	(5) Deform sexual organs ♀	(6) Determination doubtful ♂	(6) Determination doubtful ♀
1929	IV	1	1										
1928	V	3	6			1		1					1
1927	VI	6	7			2		3	2			1	1
1926	VII	4	18		3	16	13	8	13			4	5
1925	VIII		3										
1924	IX	4	14?	2	2	10	7	10	20			1	1
1923	X							2					
1922	XI		4?		1	11	8	6	24			3	3
1921	XII												
1920	XIII						1						
1919	XIV					2	2	2	3				1
1918	XV												
1917	XVI					14	16	11	11	2		1	
1916	XVII												
1915	XVIII					1							
1914	XIX						1						
1913	XX												
1912	XXI					4	1			1			
Total: 330 =		18	53	2	6	61	49	43	73	3		10	12

The 1933-spawners were, thus, those recorded in columns 2, 3 and 4. The diagram of age-distribution of the *spawning* cod (Fig. 7) is quite different to that of the whole catch (Fig. 3A). The major part of the spawning cod belong to the four year-classes: 1917, 1922, 1924 and 1926 and in almost equal proportions; the 1917 year-class being here slightly above the other three while being the smallest one in the mixed analyses.

It must be noted that cod as young as the V- and VI-groups (year-classes 1928 and 1927) appear among the spawners although by a few specimens only. Of the 1928 year-class 2 individuals had spawned while 9 were immature. The 1927-class shows 7 spawners and 13 immature.

The 1926 year-class was the youngest spawning class of any importance, with 53 spawners and 22 (or 30 %) immature.

The 1924 year-class came next with 51 spawners and 18 (or 26 %) immature.

The 1922 year-class showed 50 spawners and 4 immature only (all of which, though, were doubtful).

The old 1917 year-class did not show any immature specimens but two male individuals showed deform testis.

The 1912 year-class was represented by 5 excellent spawners, while one male had deform sexual organs.

The proportion of males to females was 137 to 193 or about 2 female to 3 male individuals.

As regards the 4 important groups the proportions were as follows:—

Table B.

year-class	all cod analysed ♂	all cod analysed ♀	spawning cod only ♂	spawning cod only ♀
1926	32	52	24	29
1924	27	44	22	29
1922	20	40	17	33
1917	28	27	25	27
	107	163	88	118

The females predominate in all classes and particularly so in the first analysis, due to the fact that the female reaches maturity later than the male.

Studying columns 3 and 4 only table A shows that more females have finished spawning. The proportions are: spawning ♂ 61, ♀ 49 and spent: ♂ 43, ♀ 73.

It is difficult to form any idea on the question of which age-group is the first one to finish spawning: whether this be the young groups or the old ones. As regards the four important year-classes the table shows the following figures:—

Table C.

year-class	spawning	spent
1926	29	21
1924	17	30
1922	19	30
1917	30	22

which seems to indicate that the oldest year-class, as well as the youngest one, have commenced spawning (and thus also finished) later than the other classes, but the 1917 year-class may have commenced spawning just as early as the year-classes 1922 and 1924, or before even, as for an old age-group spawning may be going on for a longer period; but no conclusions can be drawn from the material at hand.

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III

DANISH HYDROGRAPHICAL INVESTIGATIONS IN THE DENMARK STRAIT AND THE IRMINGER SEA DURING THE YEARS 1931, 1932 AND 1933

BY

HELGE THOMSEN

Introduction.

uring the years of 1931, 1932 and 1933 the research vessel "Dana" carried out investigations the Denmark Strait and the Irminger Sea under direction of Dr. Å. Vedel Tåning. Although the in object of these investigations were of a fishery-logical nature, and consequently the stations could be chosen from a purely hydrographical point of w, material was nevertheless collected which is of ortance to hydrographical problems in these ers.

n spite of the fact that both the Denmark Strait the Irminger Sea are of great hydrographical rest both these areas have remained unexplored modern expeditions till quite recently. Since the ish "Ingolf-Expeditions" explored these waters in 5—96 only scattered observations have been made l the German "Meteor-Expedition" in 1929 and undertook a modern systematical hydrographical mination of the Irminger Sea and the southern of the Denmark Strait.

he results of these investigations are, as yet, only ly published by Defant (1930, 1931, 1932), by necke, Hentschel and Wattenberg (1930) and Böhnecke (1931), a. o.

1929 the Norwegian "Øst-Expedition" also ed in the northern part of the Denmark Strait brought back important hydrographical material h has been published by Braarud and Ruud 2). This material derives its main importance from act that it hails from the area above the Iceland-nland Ridge, waters which are generally icebound which have not been visited by oceanographical ditions before.

1931 further hydrographical investigations were in the Denmark Strait from the Norwegian ship lling". These investigations comprise observations stations, published in 1933 in an Appendix to Bulletin Hydrographique" for 1931.

e "Dana" is a type of boat which is unsuited for in the ice and all the stations, at which observa- were made during the years 1931—32—33, are ed outside the ice-border. The material collected sts of surface observations as well as of observations from 72 stations distributed as follows: 16 stations from July 14th to July 20th 1931, 23 stations from July 8th to July 15th 1932 and at 33 stations from August 8th to August 16th 1933. These observations comprise determinations of temperature and salinity and, at some stations, also of the contents of oxygen as well as of phosphate and nitrate. No expert hydrographer took part in the "Dana-Expedition" to the Denmark Strait in 1931 the hydrographical investigations being carried out by Dr. Å. Vedel Tåning and Mr. Rae and the chlorine-titrations of water samples collected were made ashore after the return home. In 1932 and 1933 the hydrographical investigations were carried out by the writer.

The material collected during the first two years mentioned above was published in the Bulletin Hydrographique for 1931 and 1932 while that for 1933 will be published in the Bulletin Hydrographique for 1933. The chart Fig. 1 shows the position of the hydrographical stations during these three years.

Ice-conditions and surface observations.

On the chart Fig. 2 the average boundaries of the ice during the month of July and the ice-boundary during July 1931 are drawn from the Danish Nautical Meteorological Annual for 1931; the ice-border observed by the "Dana" is marked by a dotted line. The chart shows that during 1931, the extension of the ice was slightly above normal especially in the Denmark Strait proper.

From surface observations at the 16 hydrographical stations marked on the chart as well as 13 surface observations of temperature and salinity and observations of temperature taken every four hours the 8° isotherm and the 34 $^0/_{00}$ isohaline are drawn for the period July 14th to July 20th 1931. It will be observed that the 8° isotherm, which in July 1931 represents pure Atlantic water with a salinity of more than 35 $^0/_{00}$, at several points in the Denmark Strait reaches right up to the ice and rarely retreats more than 20 miles from the ice. At the station 4219 (65°58′ N., 27°30′ W.) hummocks of ice were drifting all round the ship but still the surface temperature

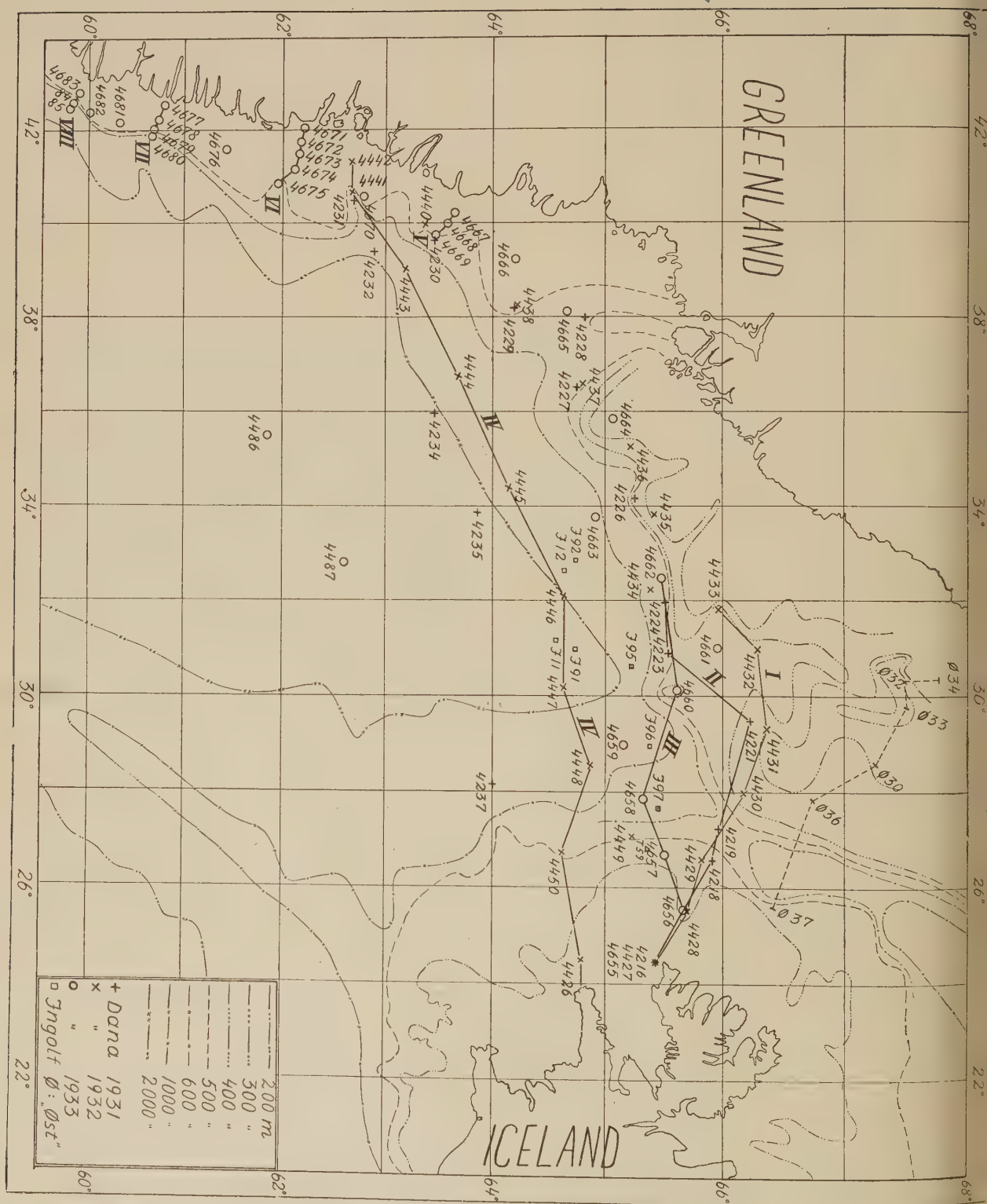

GREENLAND
ICELAND
+ Dana 1931
× " 1932
o " 1933
□ Ingolf Ø: „Øst"
200 m
300 "
400 "
500 "
600 "
1000 "
2000 "
60°
62°
64°
66°
68°
42°
38°
34°
30°
26°
22°

Fig. 1.

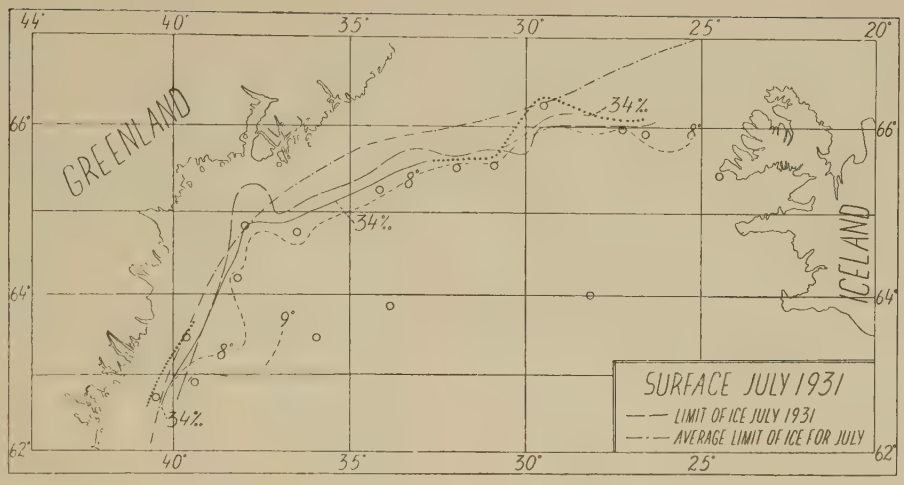


Fig. 2.

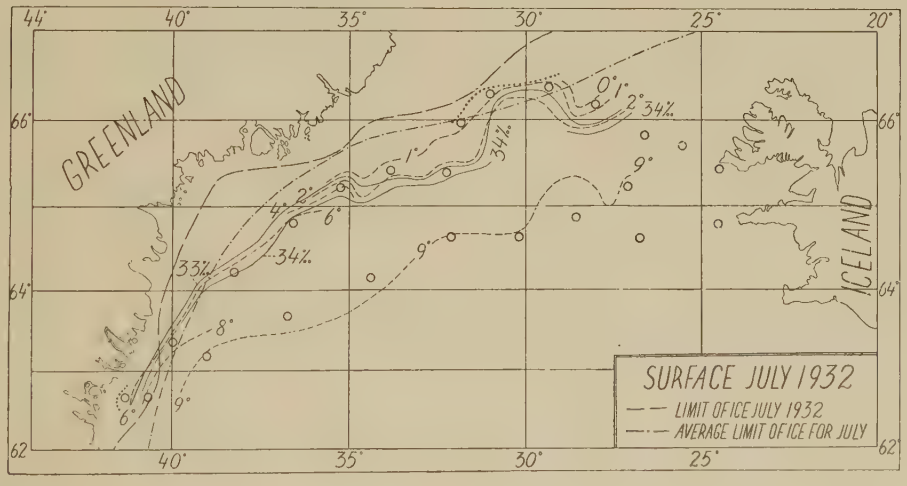


Fig. 3.

registered at 8.22° with a salinity of 35.12 ‰ ure Atlantic water. This goes to prove that the ad spread outside the boundaries of the polar nt, probably due to the effect of the wind.

. 3 is analogical with Fig. 2 in showing the hydro- ical surface conditions from July 8th to July 1932. According to the Nautical Meteorological l the appearance of ice in the area in question en smaller than normal. In this figure such iso- s and isohalines are marked as can be drawn certainty from the material collected. This ial consists of surface observations of tempera- nd salinity at the 23 stations marked on the as well as of 19 observations of temperature and y, and of observations of temperature carried very four hours.

s year polar water was found near the edge of e with a temperature right down to —0.9° and a salinity down to 32.57 ‰ in the Denmark Strait proper. At the most southerly station (St. 4442, 62°40′ N., 41°20′ W.) the lowest surface salinity was found being 31.69 ‰ with a temperature of 2.5°. We here find the upper layers of the polar current, heated during the summer and the salinity of which is reduced by the ice-melting.

In Fig. 4 isotherms and isohalines for the period from August 8th to August 16th 1933 are drawn from surface observations at the 33 stations marked on the map and 42 intermediate observations of temperature and salinity as well as measurements of temperature carried out every four hours.

While the conditions of the ice may be termed normal during the month of July 1933 (according to information kindly supplied by Commander C. I. Speerschneider) they were quite abnormal during the month of August the water being almost free from

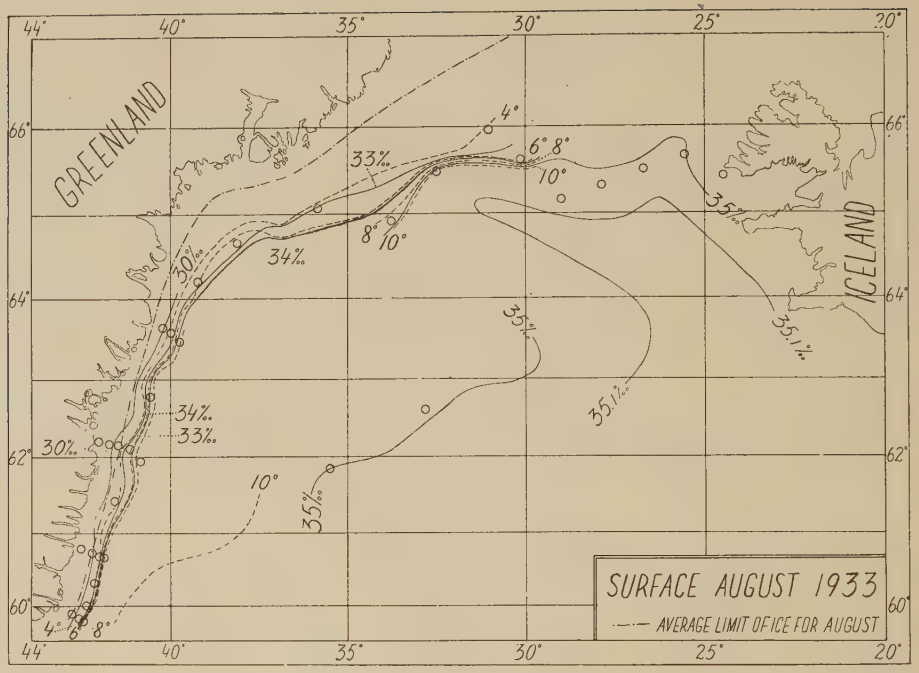

GREENLAND
ICELAND
SURFACE AUGUST 1933
AVERAGE LIMIT OF ICE FOR AUGUST
44°
40°
35°
30°
25°
20°
66°
64°
62°
60°
4°
6°
8°
10°
30‰
33‰
34‰
35‰
35.1‰

Fig. 4.

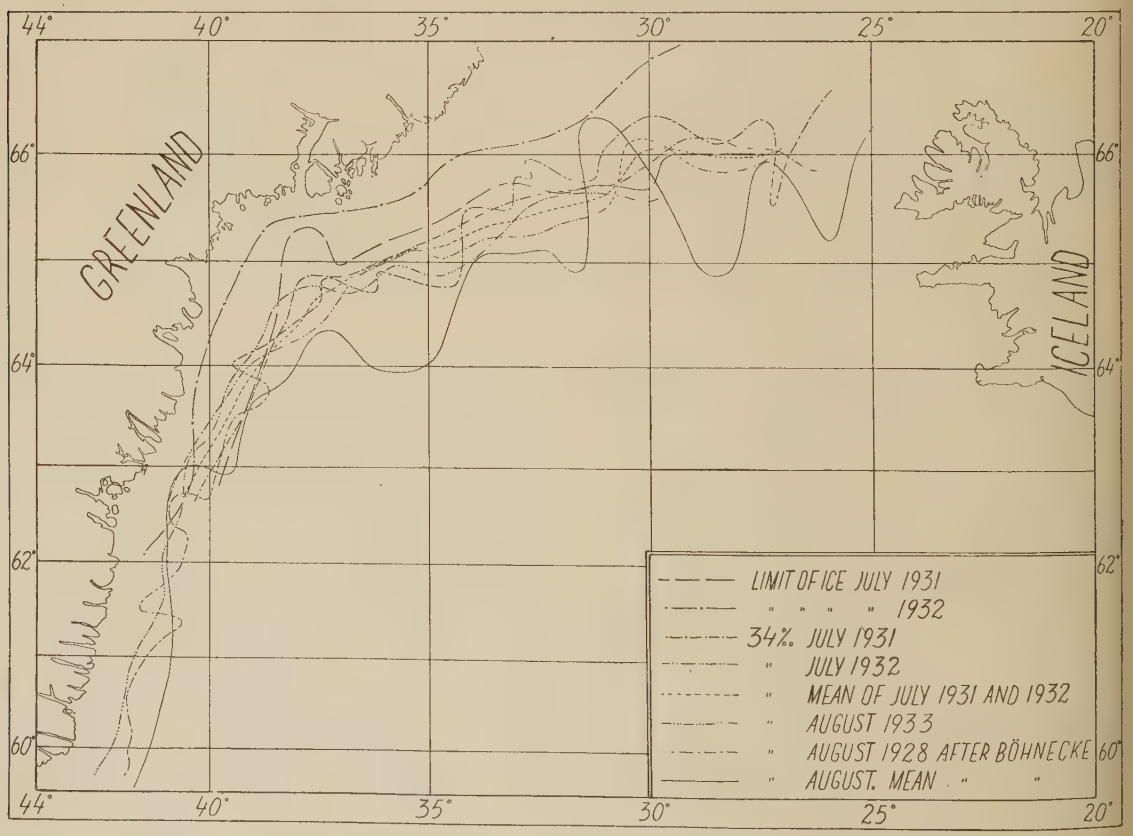

GREENLAND
ICELAND
LIMIT OF ICE JULY 1931
" " " " 1932
34‰ JULY 1931
" JULY 1932
" MEAN OF JULY 1931 AND 1932
" AUGUST 1933
" AUGUST 1928 AFTER BÖHNECKE
" AUGUST. MEAN " "
44°
40°
35°
30°
25°
20°
66°
64°
62°
60°

Fig. 5.

— except for icebergs — from the south point of enland to about 68°30′ N.
hat year polar water of a negative temperature not found in the surface anywhere. In the Denk Strait the lowest temperature was registered at most northerly station, 4661 (65°58′ N., 31°00′ W.), re a temperature of 4.1° and a salinity of 31.12 ‰ found thus characterising the water as belonging he summer-heated surface-water of the polar cur- the salinity of which is reduced by the ice- ing. At the southerly stations the salinity of the ace water is considerably reduced by the admix- of water from the melting ice especially at the ons in the vicinity of the coast, the lowest salinity noted at station 4677 with a salinity of 26.92 ‰ a temperature of 2.1° at the surface. The lowest erature 1.3° was registered at station 4667 the ity being 29.51 ‰.

order to facilitate the comparison between the nsion of the polar current during the three periods uestion the ice boundaries of each year as well e 34 ‰ isohalines have been drawn on the Fig. 5. A survey of the surface-material to [1]) shows the 34 ‰ isohaline to be the outermost e "whole" isohalines running in close parallel along the east coast of Greenland. A comparison een the 34 ‰ isohalines of 1931, 1932 and 1933 how that generally speaking only slight displace- s have taken place in the position of the 34 ‰ line. As already mentioned the observations of and 1932 were made in July and in the figure ean position of the 34 ‰ isohaline in July of two years has been drawn. Although in 1931 xtension of the ice was larger that in 1932 the current, as characterised by the 34 ‰ isohaline, s a slightly smaller extension in 1931 than in between 63° and 66° N. lat. It is only south of .. lat. that the extension of the polar current is in 1931 than in 1932. The difference in extension however, very considerable the deviations from ean contour during each various year will be o average less than 10 miles.

figure also shows that the course of the 34 ‰ ine for August 1933 does not considerably differ the 34 ‰ isohalines of July 1931 and 1932 in f the fact that the month of August 1933 was e.

ervations during the years of 1931—32—33 thus from the part of the East Greenland polar cur- e in question, to prove that no deductions made as to the extension of the polar current surface as defined by the position of the 34 ‰ ne compared with the extension of the ice. the above mentioned period the extension of the isohaline has been considerably more constant hat of the ice; in fact so constant that one say that generally speaking it has followed the eter isobath during all three years.

[1]) de e. g. Böhnecke's surface map of the mean during the month of August. Ann. d. Hydr. etc. 1931.

In order to facilitate a comparison with earlier investigations the 34 ‰ isohaline for August 1928 and the mean position of the 34 ‰ isohaline for August according to Böhnecke (1931) have also been added to the chart. It will be noted that the 34 ‰ isohaline for August 1928 coincides well with the 34 ‰ isohalines for July 1931, July 1932 and August 1933 whereas the mean isohaline for August, based on the calculation of mean salinities over 1° squares of all material then to hand, shows a considerably larger deviation especially at 35—36° W. long. and 28—29° W. long. This can hardly be due to a displacement of the 34 ‰ contour in the same direction during all those four years, it is more probable that the cause of the difference is to be found in the unreliability of the earlier observations.

Sections across the Denmark Strait.

As is well known a sub-marine ridge dividing the Greenland Sea and the Atlantic Ocean runs between Iceland and Greenland in the direction SE. to NW. The highest summits of this ridge are on the line between Staalbjerg Huk on Iceland (65°30′ N., 24°30′ W.) and Cape Edv. Holm on Greenland (67°50′ N., 32°00′ W.). In the direction SW. to NE. the ridge is cut in two by the Iceland-Greenland channel the lowest depths of which (about 550 m.) are to be found on 27° W. long. This interesting border-area has not been satisfactorily surveyed but on the chart (Fig. 1) some of the isobaths are sketched based on depths marked on the Danish chart No. 147, the soundings and the bathymetric charts of Braarud and Ruud and soundings of the "Dana" during the years 1931—32—33. The chart shows that the East Greenland shelf has a projection at about 66° N. lat. and between this and the Iceland-Greenland ridge a sub-marine fjord cuts in towards Kangerdlugsuak. This sub-marine fjord, the existence of which was assumed by Nansen and proved by Braarud and Ruud, we will for convenience sake here call the Kangerdlugsuak Deep. East of the northern part of the Kangerdlugsuak Deep the Iceland-Greenland ridge rises to less than 200 m. (the "Øst" Bank).

Once every year during the period of 1931, 1932, 1933 the "Dana" crossed this channel but in 1931 the state of the ice made it impossible to get as far north as was desirable from a hydrographical point of view and in 1933 for biological reasons the "Dana" went so far south that the Iceland-Greenland ridge was not crossed at all. Section I Fig. 6 drawn from the observations of July 8th—9th 1932 is of the greatest importance to the information about interchange of water through the Denmark Strait.

Section I reaches from Staalbjerg Huk in northwesterly direction to Station 4431 on the southwesterly slope of the Iceland-Greenland ridge and from there across the Kangerdlugsuak Deep to Station 4433 on the eastern slope of the Greenland shelf. The diagram shows that a current of warm Atlantic water with a temperature $> 6°$ and a salinity > 35 ‰

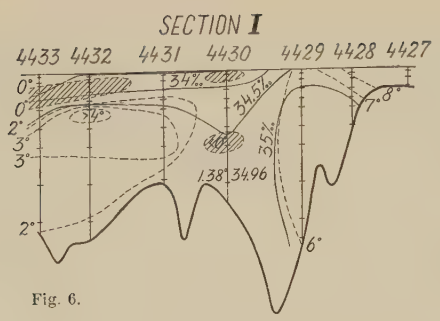


Fig. 6.

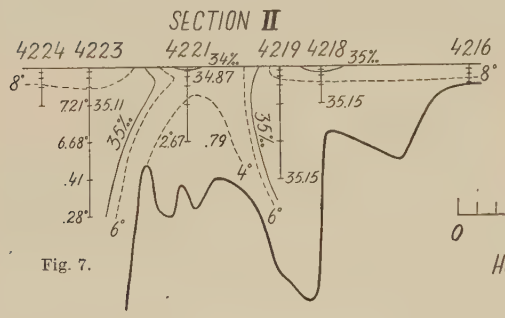


Fig. 7.

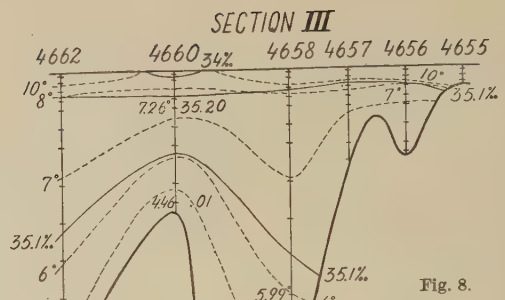
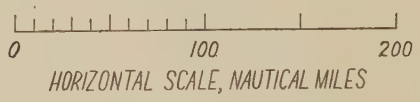
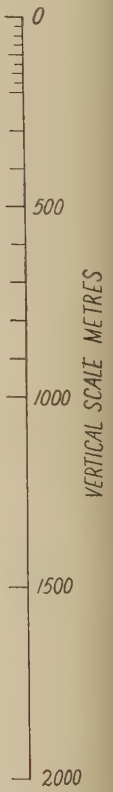


Fig. 8.





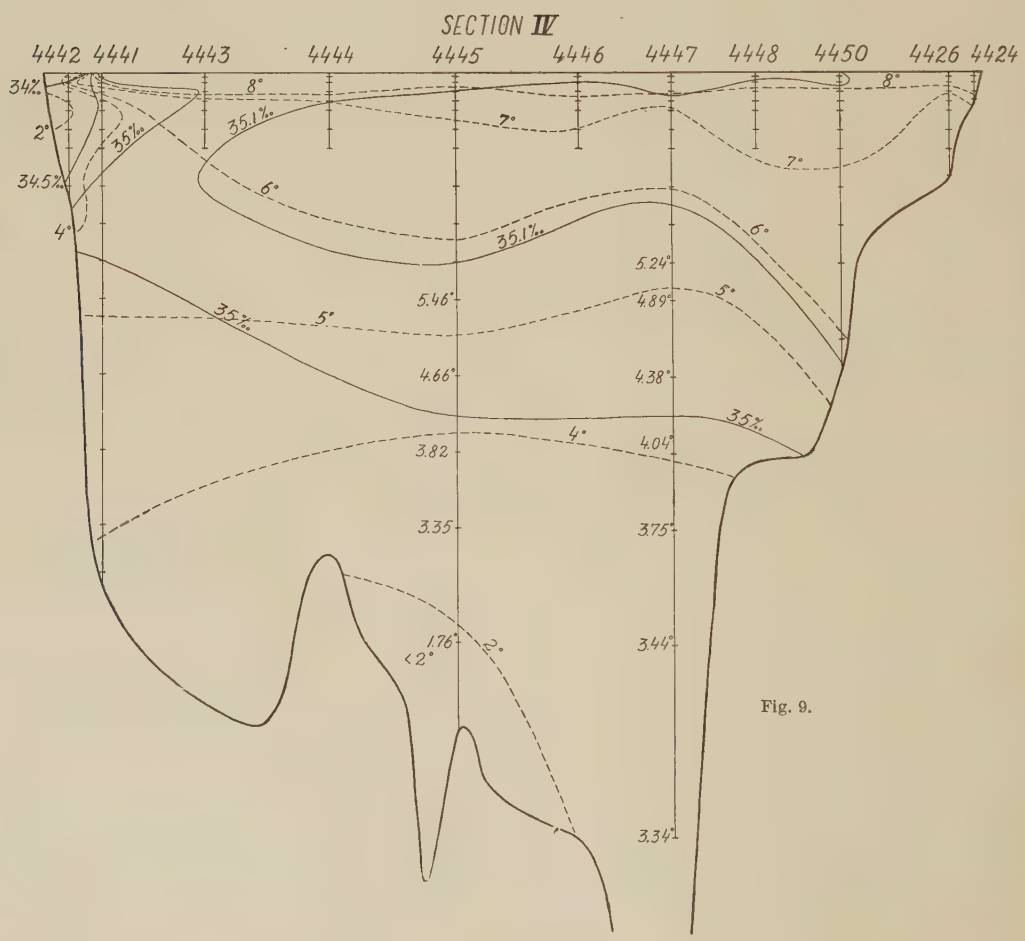


Fig. 9.

ses along the south-eastern slope of the Iceland-enland channel, while in the north-westerly part he channel we find the polar current with its low nity and a temperature as low as —0.32°. At the t northerly station (St. 4431) the layer of nega- temperature has disappeared the temperatures aining, however, low. At a depth of 200 m. we find a maximum temperature of 3.89° this being sed by an admixture of Atlantic water which is cially pronounced at the neighbouring station 2 where, at a depth of 100 m., $t° = 4.40°$, $S = 35\ ‰$. Station 4432 is situated in the centre of Kangerdlugsuak Deep where also BRAARUD and RD found an influx of Atlantic water. Above this r we again find pure polar water with a negative perature at both station 4432 and station 4433. section shows that the pure polar water as defined $t° < 0$ is divided into two branches an easterly a westerly one by the influx of Atlantic water e the Kangerdlugsuak Deep.

nalogical conditions were found by BRAARUD and D (1932 pag. 18) in a section situated a little ier north (see Fig. 1). Atlantic water was found tation 37, in the eastern part of the Iceland-nland channel, at stations 36 and 30 pronounced water ($t < —1°$), and at stations 33 and 32 a less pronounced, but yet pure polar water $t > —1°$) and again pronounced polar water —1°) at station 34.

is characteristic distribution of polar water and tic water seems to be a constant phenomenon e hydrographical conditions on the Iceland-land ridge it having been noted both at the ern "Øst" section drawn from observations from 17th to August 17th 1929 and at the southern a" section on July 8th and 9th 1932.

. 7 shows section II (cf. Fig. 1) drawn from ob-tions made from July 14th to July 16th 1931. section I Atlantic water is found in the eastern of the Iceland-Greenland channel (St. 4218 and as well as on the southern slope of the Green-shelf (St. 4223 and 4224). At station 4221, on outh-western slope of the Iceland-Greenland an admixture of water from the eastern branch polar current becomes evident. While at the e the temperature is 4.29° and the salinity is ‰ they increase to $t = 5.78°$ and $S = 34.87\ ‰$ depth of 25 m., this being due to an influx of ic water which forces its way through the rdlugsuak Deep. Below the 25 m. depth tem-re and salinity again diminish till the greatest of observation, 200 m., is reached where 67°, $S = 34.79\ ‰$.

ion III, Fig. 8 (cf. Fig. 1) is based on observa-rom August 8th to August 10th 1933 and starts se from 1931 and 1932 at Staalbjerg Huk but in nearly western direction and therefore does ss the Iceland-Greenland ridge. Atlantic water d at all the stations and at all depths excepting 0 only where $t = 4.90°$, $S = 33.65\ ‰$ are t the surface. This low temperature and salinity are probably caused by an off-shoot of the eastern branch of the polar current; already at a depth of 25 m. the temperature increases to 9.60° ($S = 34.78\ ‰$) while at depths of 50 m. and 75 m. the salinity is above $35\ ‰$. It is notable how the isolines follow the profile of the bottom and rise considerably at station 4660.

Unfortunately, in the sections I, II and III, observations from the deeper part of the Iceland-Greenland channel are missing thus making it impossible to prove the, according to NANSEN (1912), considerable influx of water from the deeper strata of the Greenland Sea with a temperature varying between 1° and 0° which passes over the saddle of the Iceland-Greenland ridge and contributes to the formation of the bottom-water in the western deep of the Atlantic Ocean, but in section IV Fig. 9 which reaches from Tingmiarmiut on Greenland to Snefjældsnæs on Iceland and which is drawn from observations made in July 1932 a temperature of 1.76° and a salinity of $34.96\ ‰$ are found at a depth of 1500 m. (Station 4445). This temperature and salinity must be caused by water which has come from the north into the Iceland-Greenland channel and has passed along the right-hand slope. At all the other stations in this section, excepting those nearest to Iceland and Greenland, Atlantic water is found with a temperature and salinity diminishing as the depth increases. The greatest depth (2450 m.) is recorded at station 4447 where a temperature of 3.34° and a salinity of $34.98\ ‰$ are found at a depth of 2000 m., i. e. a temperature and a salinity slightly above that of the bottom-water of the North Atlantic, the temperature and salinity of which can be considered 2.5° and $34.90\ ‰$ (JACOBSEN 1929).

Analogical conditions were found by the "Ingolf" Expedition (KNUDSEN 1899), the temperatures found in 1895 at the stations I 11 and I 12 (see Fig. 1) being below 2° at the bottom, 1.6° at a depth of 2448 m. and 0.3° at a depth of 1958 m. respectively. At the stations I 91, I 92, I 95, I 96 and I 97 respectively the following temperatures were registered in 1896: 3.1° (2328 m.), 1.4° (1838 m.), 2.1° (1416 m.), 1.2° (1384 m.) and 5.5° (847 m.). These temperatures seem to indicate that in 1895 and 1896 also cold water from the north has passed into the deepest part of the Iceland-Greenland channel and turning to the right it has descended along the continental slope. This influx of water from the Greenland Sea over the saddle of the Iceland-Greenland Ridge does not seem to be a constant one. At station I 11 for instance the temperature at the bottom was 1.6° (2448 m.) in 1895 while in 1896 the temperature at the bottom registered at station I 91, some 10 miles north-east of station I 91 was 3.1° (2328 m.) i. e. the expansion of cold water has been larger at the time of observation in 1895 than in 1896. It must be remembered, however, that the thermometres of the "Ingolf" Expedition, especially those applied during 1895 (Stations I 11 and I 12), hardly correspond to modern thermometres as regards reliability, and the comparison of the

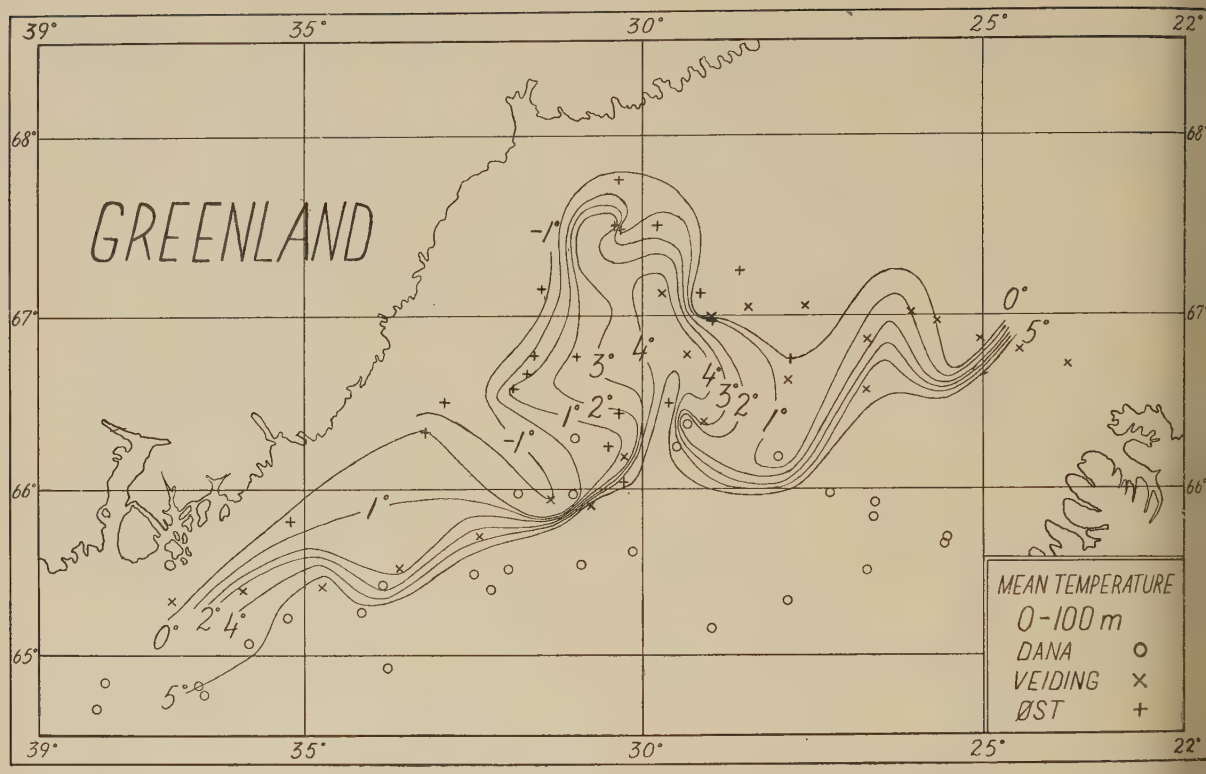

39°
35°
30°
25°
22°
68°
67°
66°
65°
GREENLAND
-1°
0°
1°
2°
3°
4°
5°
8
MEAN TEMPERATURE
0-100 m
DANA
VEIDING
ØST

Fig. 10.

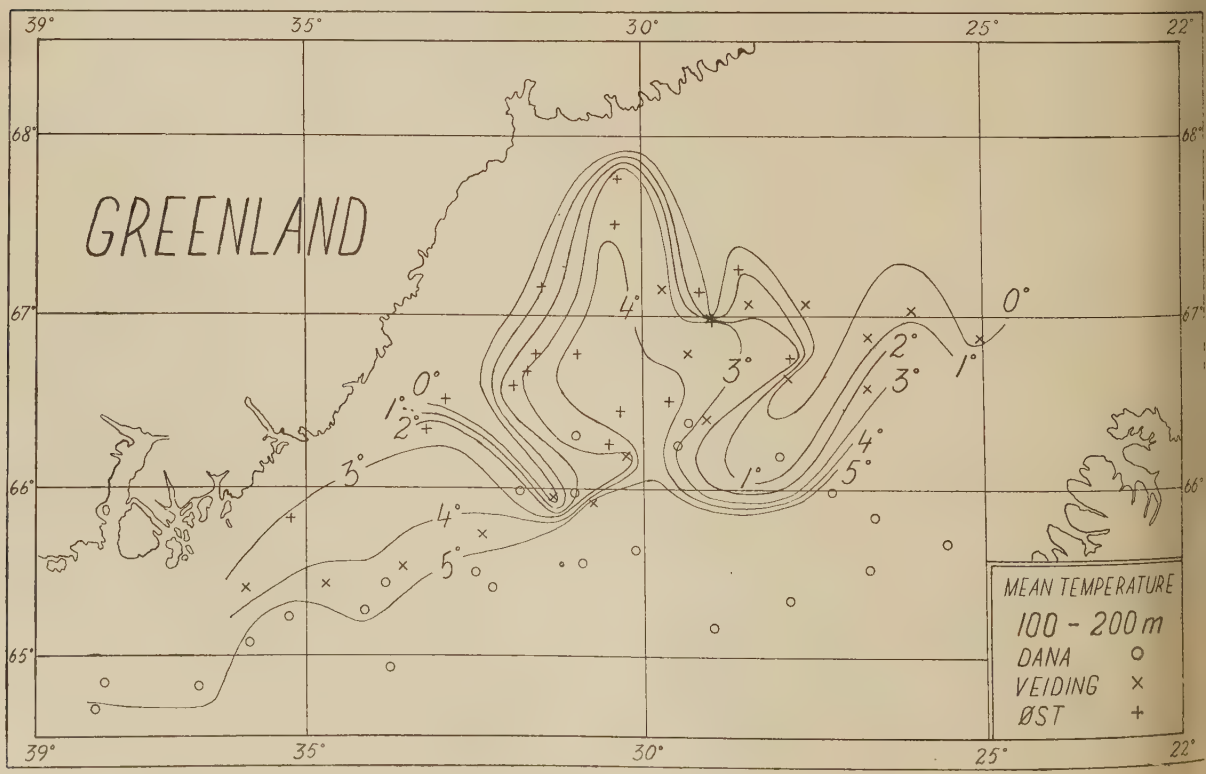

39°
35°
30°
25°
22°
68°
67°
66°
65°
GREENLAND
0°
1°
2°
3°
4°
5°
MEAN TEMPERATURE
100 - 200 m
DANA
VEIDING
ØST

Fig. 11.

ension of the cold water in 1895 and 1896, there-
, must be taken with some reservation.

ANSEN (1912, pag. 21) applies the observations of "Thor" station 59 (65°21′ N., 26°50′ W.) in a ion showing the penetration of cold water from deeper strata of the Greenland Sea through the and-Greenland channel. At this station, on June 1904, the following data were recorded (NIELSEN 5):

	$t°$	$S\,‰$	σ_t
.....	5.09	35.02	27.70
.....	1.76	34.70	.78
.....	0.21	.72	.89
.....	0.04	.92	28.08

he recent observations from the "Dana" as well ther "Thor"-observations from 1904 show that observations at "Thor" St. 59 cannot be con-ed typical of the watermasses at this place, the on being situated at the eastern slope of the nd-Greenland channel. Most probably this station taken in a hole, which at a certain time has been lowed by and filled up with cold, heavy water, remained when later on the cold water in the r strata was replaced by Atlantic water. This anation would support the hypothesis that the nt of cold water over the saddle of the Iceland-nland ridge is very irregular, perhaps varying the season. During the summer season the current the saddle seems to be so insignificant that it y can play any role in the forming of the bottom of the North Atlantic.

horizontal distribution of polar water Atlantic water in the Denmark Strait.

order to make a survey of the distribution of water and Atlantic water across the Iceland-land ridge in the upper layers, mean values of erature for the layers between 0 and 100 m. and en 100 and 200 m. has been calculated, by ical integration, for all stations of the "Øst", ing" and "Dana" in the area under discussion. means express the total content of heat in the column in question and considering that the waters, the cold polar water and the warm ic water, are the only ones to be considered at depths the mean temperature of the water n will give us an idea of the quantities by which o characteristic water masses appear in the column, presuming that such deviations in the temperature as may be due to melting of ice eating by the sun is of such small importance connection that it need not be considered. d on the mean figures from all stations in observations have been made down to depths m. or more the mean isotherms for the water etween 0 and 100 m. has been drawn in Fig. 10.

In spite of the fact that the material hails from 4 different years the mean temperatures are easily compiled with smooth running isotherms.

As also shown by BRAARUD and RUUD by their horizontal sections it will be seen that the warm water penetrates northwards along the eastern side of the Kangerdlugsuak Deep; at about 30° W. Long. the 3°-isotherm bends northwards from about 66° N. Lat. to about $67\frac{1}{2}$° N. Lat., a distance of nearly 90 miles. At "Øst" station 35 (67°30′ N., 30°24′ W.) the mean temperature for the water layer 0—100 m. is 3.06°.

The cold polar water penetrates southwards along the north-eastern slope of the Iceland-Greenland ridge and so far south that the 1°-isotherm almost reaches down to the 66° N. Lat., at 28° W. Long., the temperature at station 4430 (66°10′ N., 28°00′ W.) being 0.86°.

East of this cold water the Atlantic water penetrates northwards through the Iceland-Greenland channel but at $66\frac{1}{2}$° N. it is forced right across to the eastern side of the channel by a branch of polar water at about $25\frac{1}{2}$° W.

Another branch of the polar current with very cold water west of the Kangerdlugsuak Deep penetrates in south-easterly direction following a projection of the Greenland shelf. At the "Veiding" Station 165 (65°56′ N., 31°22′ W.) the mean temperature is —1.01°, and at the two "Dana" stations close by, viz. 4433 (65°58′ N. Lat., 31°50′ W. Long.) and 4661 (65°58′ N. Lat., 31°00′ W. Long.) the temperatures are —0.38° and —0.41° respectively.

Fig. 11 shows the mean isotherms of the water layer between 100 and 200 m. It will be noted that the special character of the isotherms shown in Fig. 10 are repeated here, but the mean temperature of this layer is generally higher at the northern stations than that of the water layer above, due to the fact that Atlantic water generally penetrates below the polar water. Station 4430 on the western side of the Iceland-Greenland channel shows a mean temperature of 0.36° and at the most northerly station in the Kangerdlugsuak Deep: 3.15° ("Øst" station 34, 67°45′ N. Lat., 30°21′ W. Long.). West of the Kangerdlugsuak Deep a similar bend in the isotherms as that shown in Fig. 10 will be noted with a mean temperature of —0.46° at the "Veiding" station 165 (65°56′ N. Lat., 31°22′ W. Long.).

It has already been mentioned that the observations from the years 1929, 1931, 1932 and 1933 could be arranged without difficulty to show the shape of the mean isotherms for the water layers between 0 and 100 m. and between 100 and 200 m. as indicated by Figs. 10 and 11. It may therefore be anticipated that the above mentioned main features of the distribution of cold and warm water during summer is a comparatively constant phenomenon in the Hydrography of the Denmark Strait although minor deviations may of course be expected in the position of the isotherms from year to year. As also mentioned by BRAARUD and RUUD the distribution of water seems to be highly dependant on the morphological conditions,

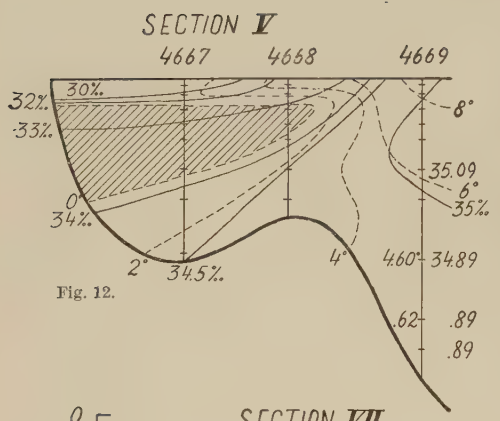
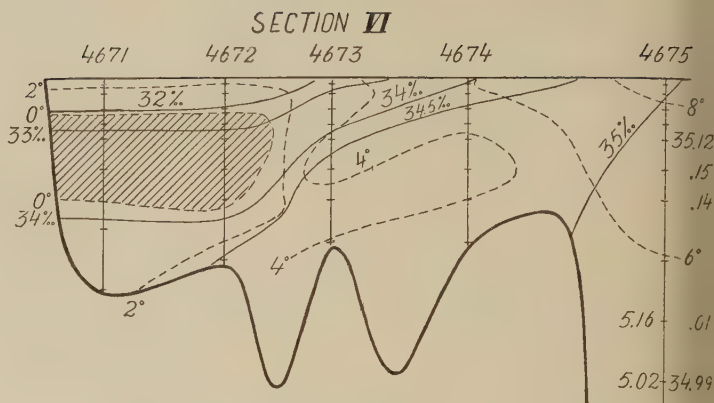


Fig. 12.



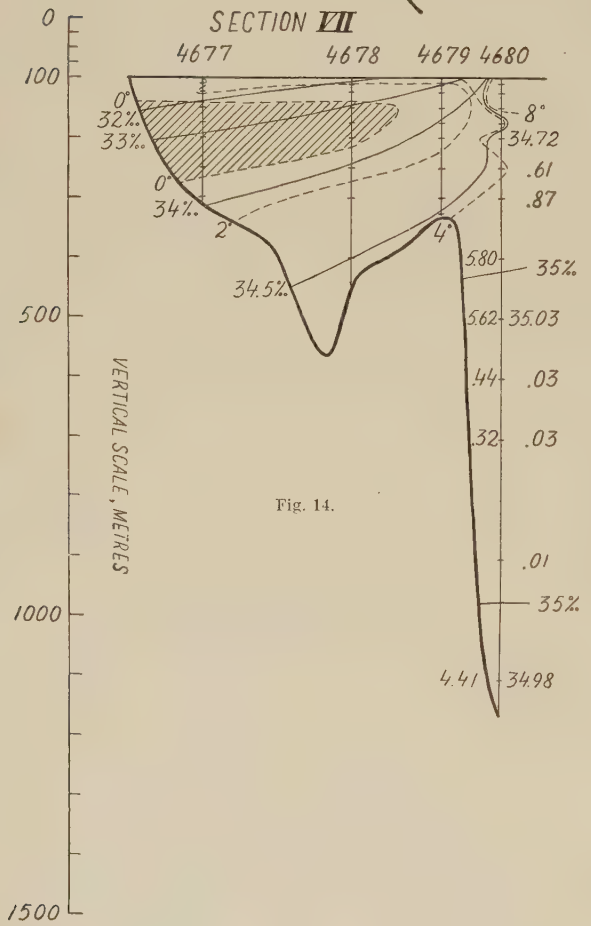


Fig. 14.

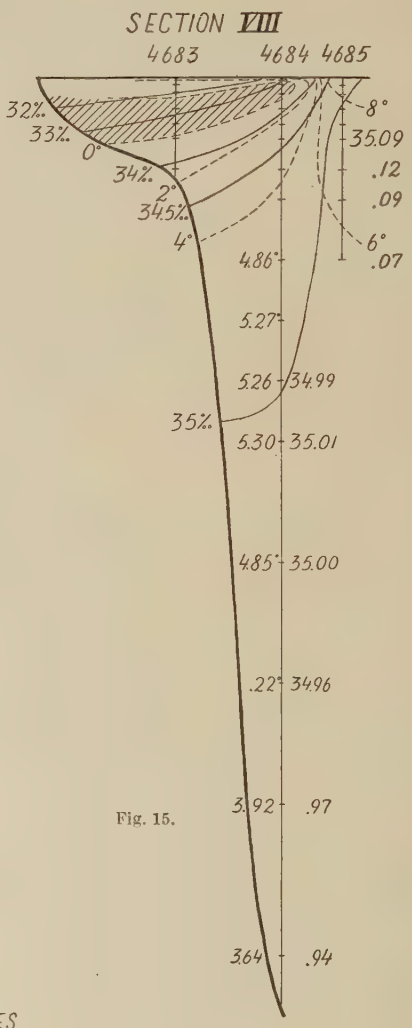
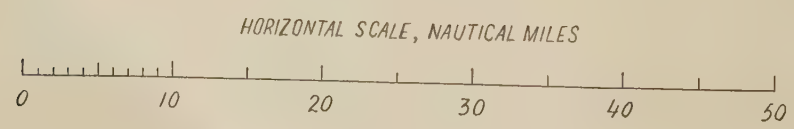


Fig. 15.

Fig. 13.



e e. g. the penetration of warm water towards th in the eastern part of the Kangerdlugsuak Deep l the penetration of cold water southwards along north-eastern slope of the Iceland-Greenland ridge.

ections across the East Greenland Polar Current.

hanks to the favourable ice- and weather-con-ons in 1933 it became possible to approach quite se to the Greenland coast and make some sections t across the polar current. Four such sections were le, their positions being shown on the chart . 1). The determinations of the geographical coor-ates of the stations may be considered correct for stations in the sections VI and VII, whereas the dinates of the stations in the sections V and VIII less accurate due to misty weather. The distance, ever, between the stations of all the four sections true. The diagrams of the sections are shown in figures 12, 13, 14 and 15.

n all four sections pure polar water with a nega- temperature was found near the coast at depths rom 50 to 150 m. This belt of pure polar water a comparatively constant horizontal extension in Four sections reaching about 18 miles from the t in section V, about 15 miles in section VI, t 18 miles in section VII and in section VIII t 17 miles from the coast.

he vertical extent of pure polar water, on the rary, is not so evenly distributed in the four ons being largest in section VI where at the two ons nearest the shore pure polar water was tered at depths from 60 to 200 m. In the more herly section VII pure polar water reaches depths m. to about 170 m. at the innermost station, the most southerly section VIII from depths of t 30 to about 100 m. at the innermost station. e minimum temperature also diminishes numeri- from section VI to section VIII as shown by the wing numbers:

	St.-No.	*m.*	*t*°
on VI.....	4672	100	—1.33°
VII.....	4678	75	—1.13°
VIII.....	4683	50	—0.64°

is decrease of the temperature and extent of the polar water is a natural consequence of the inter- re with Atlantic water which becomes more and noticeable further south. The core of the polar rises simultaneously towards the surface.

y the most northerly section V forms an ex- on to this general rule. Pure polar water is found there between the depths of approximately 40—160 m. with a minimum temperature of —1.15° at 75 m. at the innermost station (4667) i. e. its vertical extent as well as its minimum temperature are below those of the more southerly section VI.

Probably this is due to the above-mentioned uncertainty regarding the geographical coordinates of the stations in section V. If the three stations 4667, 4668 and 4669 *de facto* should be situated some few miles more easterly, one might expect to find a lower minimum-temperature of the polar water on a station nearer to the coast as well as a greater vertical extension of the layer of negative temperature.

In all these four sections a layer of water with a greatly reduced salinity due to melted ice is found above the pure polar water. This layer has its largest extent in the vicinity of the coast where 32 ‰ isohalines are registered at a depth of about 50 m. in all four sections. The lowest salinity is also found in the vicinity of the coast where, at the innermost stations of sections V, VI, VII and VIII, respectively, it is registered at 29.51 ‰, 27.52 ‰, 26.92 ‰ and 29.88 ‰. As was to be expected the salinity diminishes toward the south; it is true that, at the most southerly station, a comparatively high salinity of 29.88 ‰ is found, but this station is situated at a comparatively long distance from the shore so that it may be taken for granted that the salinity would be found to be considerably lower nearer the coast.

At the outermost stations all sections show pure Atlantic water with a salinity of above 35 ‰ and between this and the pure polar water there is an area of intermixed water the width of which corresponds to the width of the shelf reckoned to the 300 m. isobath (see table).

	Width of pure polar water	Width of mixed water	Sum	Width of shelf
Section V.....	18	6	24	25 miles
— VI.....	15	24	39	35 —
— VII....	18	8	26	22 —
— VIII...	17	4	21	11 —

The above table proves that the area of mixed water is wider where the shelf is widest (section VI) and narrower where the shelf is narrowest (section VIII). It also shows that the widths of the polar water and of the intermixed water together, which represent the distance from the coast of the pure Atlantic water, almost correspond with the width of the shelf; in the most southerly section only where the shelf is particularly narrow (about 11 miles) the Atlantic water does not reach the shelf; on the basis of observations at stations 4684 it is, however, permissible to surmise that it is present on the continental slope at a depth of 500—600 m.

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IV

MARKING EXPERIMENTS WITH PLAICE IN EAST ICELANDIC WATERS

BY

Å. VEDEL TÅNING

Introduction.

In "Marking Experiments on Plaice and Cod in Icelandic waters"[1]) Johs. Schmidt in 1907 gave a review of the first results of the Plaice marking experiments in those waters. The experiments had several objects in view, some of which may be mentioned (l. c. p. 3): (1) to obtain materials for a comparison between a region, containing large quantities of Plaice but with a low fishing intensity, and another, e. g. North Sea, where the Plaice fishery was carried on with great intensity; (2) to study the growth of the Plaice; (3) and to study its migrations in this northerly region with its well-marked hydrographical characteristics. In the years following the publication of the 1907 report a number of marks were received concerning the Plaice marked in Vopna Fjord on the east coast of Iceland, and Bjarni Sæmundsson wrote a report on these in 1913[2]). Altogether 37 recoveries were reported of the 494 Plaice marked, thus 7.5 %, which is several times lower than the recovery percentage for Plaice in the North Sea at that time; almost all were taken by British or German trawlers (only 2 by Icelandic boats). With regard to migrations the experiments showed, that the Plaice as maturity approached migrated for the most part from the cold east coast to the warmer south coast, where 14 specimens were recaptured (see Chart Fig. 1a). Lastly, the experiments showed that the Plaice at East Iceland grew about 2.3 cm. in the year, for sizes about 30—40 cm. in length, thus a slow growth.

In 1931 Professor Johs. Schmidt arranged for the repetition of these marking experiments after an interval of about 25 years, in order to observe the changes which may have arisen in regard to the three main points. During the intervening years no Plaice marking experiments had been made on the east coast, though such experiments had been carried out on the north, west and south coasts after the war.

In the following pages I shall deal with the results obtained, though I may add that some of the marked Plaice will certainly be reported later. Nevertheless the migrations within the first year in the Icelandic region are of greatest interest, since we cannot tell, in the case of specimens returned later, when the waters where they were marked were forsaken.

In this paper everywhere we compare the results obtained with those of the interesting experiments in 1905; in the Tables also we include data from the earlier experiments of 25 years ago.

[1]) Medd. Komm. for Havundersøgelser. Serie Fiskeri. Bd. II. No. 6. 1907. København.

[2]) Ibid. Bd. IV. No. 6. 1913.

Material.

The 1931 marking of Plaice in the Vopna Fjord was carried out by the "Dana" from the 2nd to the 3rd of August on the south side of the Fjord in the neighbourhood of Krossavík. The depth was about 18—34 m., bottom sandy with large amount of seaweed. The 50-foot otter-trawl of the "Dana" was used for the fishing. The ground chosen allowed of hauls of half an hour's duration; the Plaice were set free one by one almost at the same spot where they were fished, though usually a little outside the actual trawling ground. About 238 Plaice were taken in 9 hauls and of these 227 were marked, about half a score being rejected (less than 30 cm. in length). Table 1 gives the length of the specimens, as also that of the sample of Plaice marked at the same place in 1905.

Table 1.

Number of Plaice marked 1905 and 1931 in Vopna Fjord, East Iceland. Distribution in 5 cm. groups[1]).

5 cm. groups	1905	1931
65—69	3	..
60—64	5	..
55—59	8 (1)	1
50—54	4	..
45—49	28 (2)	9 (1)
40—44	53 (4)	25 (5)
35—39	159 (5)	83 (5)
30—34	153	82 (3)
25—29	64	27
20—24	17	..
Total...	494	227

[1]) In brackets number of Plaice (belonging to the various size groups, final size) recovered from South Iceland west of about Wester Horn: smallest specimen 1905 35.0 cm., 1931 33.2 cm.; see further p. 10.

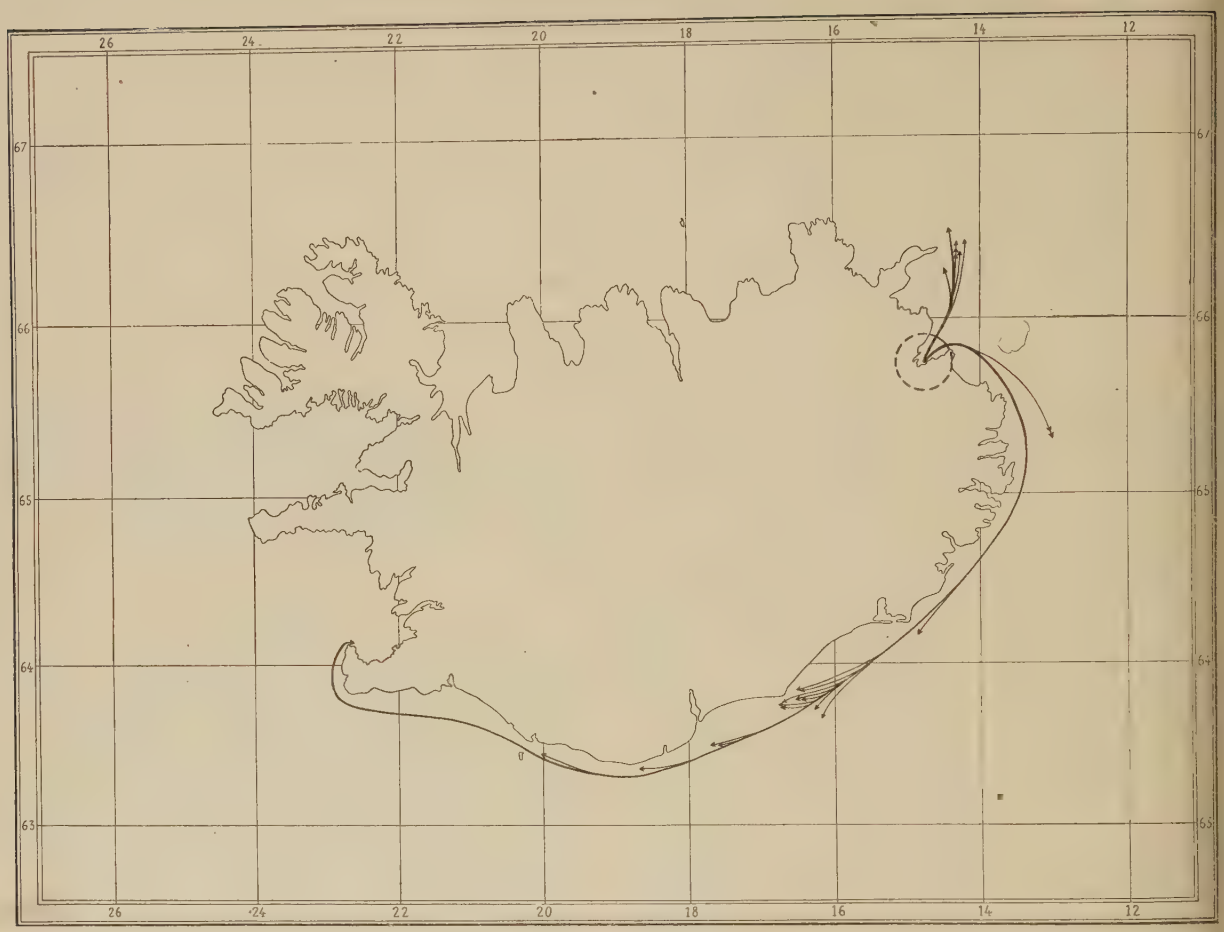

Fig. 1 a. Migrations of Plaice in the **1905** experiment. Inside the circle (10 miles radius) 5 stationary specimens.

In 1905 the length distribution between 25 and 45 cm. was almost the same as in 1931; but in 1905 about 10 % of all the Plaice were from 45 to 70 cm. in length against only about 4 % of these large Plaice in 1931. This is naturally due to the fact, that in 1905 the locality housed a stock very little or not at all fished, whereas by 1931 the stock had become more or less well fished.

Details regarding the 61 Plaice reported as retaken will be found in the Table at the end. Three of the marks have been received with such imperfect or uncertain information that we can say little more than that the Plaice in question were recaptured at Iceland in the year after liberation. In some cases the data about the localities are quite uncertain, as also regarding the lengths of the Plaice; hence the extent of the migrations, growth of the Plaice etc. contain as usual a certain amount of error.

The sex of the Plaice was determined during the marking by holding them up against the light; but as the pigmentation in the skin of Icelandic Plaice is extremely dense, this determination is somewhat uncertain. On marking the Plaice were measured to the nearest, lower cm.; the average has thus to be corrected by + 0.5 cm. The marks were those ordinarily used in Denmark, of ebonite with a connecting silver wire. Only hardy specimens were marked; as the marking needle now generally employed by us was used, the marking of each specimen took less than 30 seconds.

A. Migrations.

The present experiment shows, in an interesting manner, that the emigration of the Plaice from the cold waters of the east coast to regions, where they meet the warmer and salter waters of the Atlantic, is a regularly recurring, biological phenomenon which happens yearly in the case of at least the majority of the specimens approaching maturity for the first

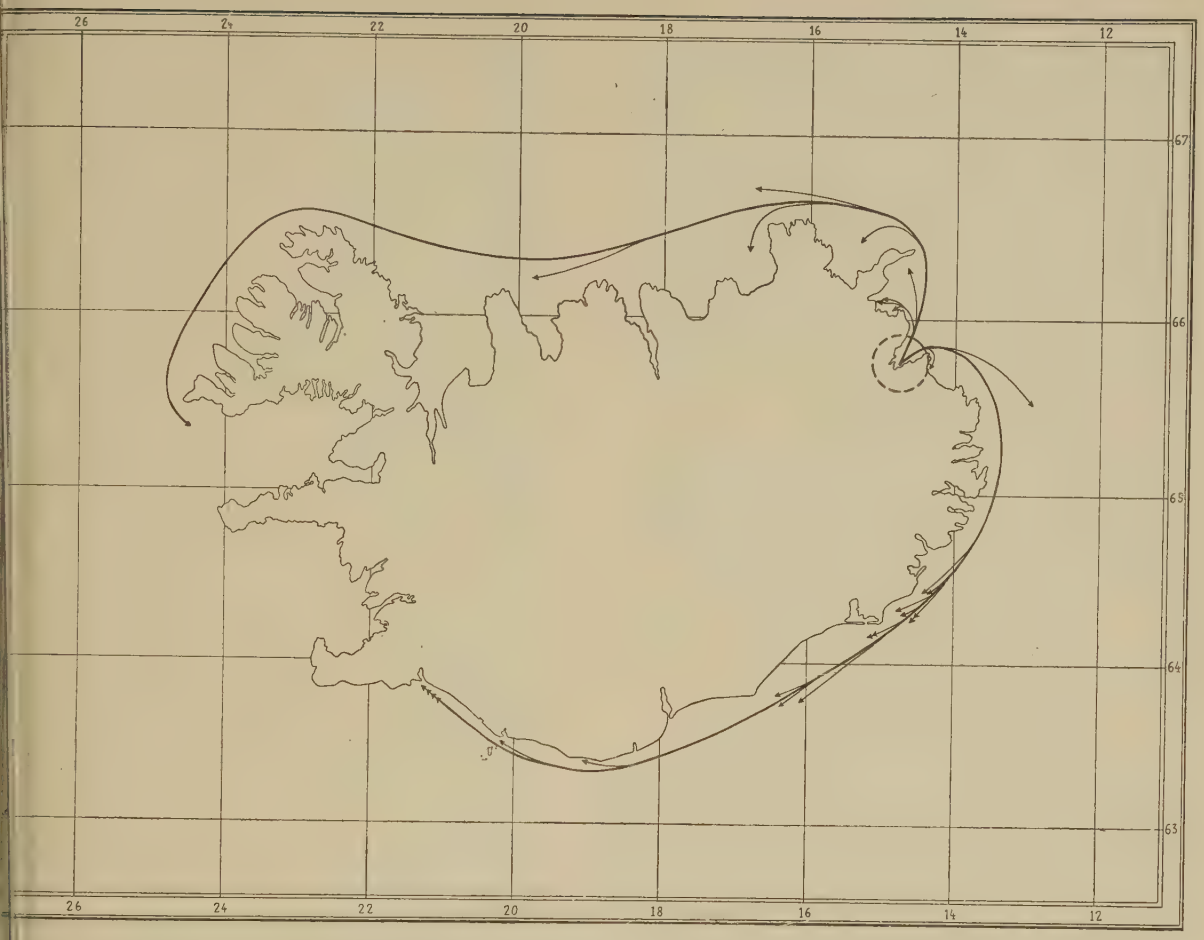

Fig. 1 b. Migrations of Plaice in the **1931** experiment. Inside the circle (10 miles radius) 29 stationary specimens.

Comparison of the 2 charts (Figs. 1a & b) reveals st glance the great identity between the exper- ts of 1905 and 1931. The reason for this interesting arity is assuredly, apart from the topography of oastal banks, the existence of the, on the whole, mely characteristic hydrographical conditions in waters.

may be objected, possibly, that the 1931 ex- ent has displayed a greater migration north- s round the island than was the case in 1905. is seemingly correct, and one might be inclined ribe it to a greater intensity of that part of the ger Current, which comes from the west along orth coast, reaching presumably the east coast g the summer in most years, and which possibly be regarded as the outer stimulus to the tion northwards round the island. But one has to hat since 1905 the trawl fishery has undergone considerable changes there, as it is now carried erywhere where there is any possibility of work- ith the apparatus now used. In any case there is now considerably more fishing on the banks north of Iceland than was the case 25 years ago when the stock on the more easily fished banks on the south and west coasts were still at the height of their productivity after the first beginnings of the trawl fishery at Iceland (1891). The chances for obtaining information regarding Plaice recaptured on the north coast have undoubtedly increased and for this reason we can hardly attach any fundamental importance to the difference mentioned. We can see also from the 1905 chart, that the trawlers which then worked on the well-known Langanes Bank caught a number of Plaice on their way towards North Iceland (in April to September).

We may here interpose a few words regarding the limitation of the experiments owing to the seasonal changes in the fishery within the territorial limits at Iceland. Whilst the trawlers work on the banks round the island practically the whole year round, the coastal fishery with Danish seine was restricted by law in the years of the marking experiment to the

later months of the year; in 1931 August to December, in 1932 July to December[1]).

In the months January to June the trawlers have recaptured 15 Plaice, but in the second half of the year only 2—3. In the warmer half of the year, when the Plaice approach the coast, the chances are thus not on the side of the trawlers. The following numbers have been retaken by trawl and seine in the respective months.

Table 2.

Results from different fishing apparatus.

Month		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	?
Seine etc.	1931									8	1			
	1932							4	17	9	2	1		
Trawl	1931												1	
	1932	1	3	1	2	6	2	1		1				1

In judging the material one must constantly keep in mind this one-sidedness (with regard to season) in the two methods of fishing, as displayed in the Table. In contrast to many other places only 10 specimens (ca. 17 %) have been retaken in the course of the first 5 months after marking, whilst about half of all recaptures (30 = 49 %) were retaken a whole year later; this results naturally from the special fishery conditions in those remote regions.

1. Direction of the Migrations.

With the help of the two charts (Fig. 1 a and b) we have already noted how the migration from the east coast goes, partly southwards, partly northwards. The following small Table gives a numerical review of this, showing that more than twice as many individuals have wandered towards the south than to the north, and this applies both to 1905 and 1931. (One must remember here, however, as noted above, that the fishery on the banks at South Iceland is more intensive than at North Iceland). Further, it can be seen from the Table, that the fishery in the fjords of the smaller craft at North-East Iceland has increased considerably in 1931—32 by comparison with 25 years previously.

Table 3.

Direction of migration.

	1905		1931	
	No.	%	No.	%
Stationary ..... (Vopna Fjord and Nyps Fjord)	5	13.5	29[3])	47.5
Migrated north	7	18.9	9	14.8
— south	17[1])	45.9	19[2])	31.1
?	8	21.7	4	6.6
Total...	37	100	61	100

[1]) Of these 2 had not yet gone beyond Lónsvík, S. E. Iceland.
[2]) - — 4 — — — —
[3]) Possibly 30.

None of the recaptures from the south coast in the 1931 experiment would indicate, that a migration has taken place from the east coast to the south coast by way of North and West Iceland; we have received one Plaice only from N.W.-Iceland where much trawling is carried on; from there, however, we have quite a number of records of recaptures from marking experiments made on the north coast. In the 1905 experiment a single specimen was recaptured off Reykjanes, otherwise none on the west coast; this specimen was supposed to have migrated southwards round the island.

If we now seek for an explanation of the picture we have obtained of the emigration away from the east coast, we come to the difficulty of understanding the factor directing the wanderings of the Plaice after some outer or inner stimulus has initiated the movement as a link in the sexual cycle (the migration from the east coast, so far as we know, is only taken part in by individuals approaching maturity). Wherever the requirements of the ripening Plaice, with regard to the physical and chemical factors of the surroundings, are satisfied at the locality where they happen to be, more or less by chance, hardly any long migration takes place (only till a certain depth is reached); but we know from our knowledge of the biology of the Plaice in the waters of East Iceland[1]), that the physical and chemical requirements at the spawning period are not satisfied there (at the most only in certain years, at certain localities and always only for comparatively few individuals). Consequently, if a single physico-chemical factor is of determining influence, we have only to review the known differences between the conditions on the east coast and those on the coasts where the main spawning occurs, to discover what it is that determines the route of migration and so leads the Plaice that their goal — the warmer and salter water at a certain depth — is attained. When the goal which suits the individual is reached, do the Plaice stop there (or do they go on wandering until the urge to migrate is dissolved by the spawning itself?).

Before going further we may remark, that we consider any discussion of the possibility that inherited tendencies or unknown senses (inherited memory, sense of direction etc.) determine the route or guide the Plaice, as quite unnecessary so long as more appreciable and practical means of explanation are to be found.

The most appropriate explanation of the wanderings of the Plaice during this period of their life-cycle would seem to be, that they move away from the unsatisfying waters (in the depth suitable for them) against the current, which conveys water of the physico-chemical nature that more nearly answers the requirements of the Plaice in the spawning period, specially as to temperatures. The water movement round Iceland is, as is known,

[1]) A new regulation of the Plaice fishery has come into force in 1933.

[1]) cf. TÅNING: Plaice investigations in Icelandic waters, 1929.

nticyclonic on the whole, and we might therefore ppose that the Plaice towards the end of the year, en with the arrival of a very small amount of armer and salter water from the north coast (Irmin- r Current in its eastern branch), would be guided wards the north. So far, indeed, we have no know- lge of any inflow to the east coast directly from the uth; consequently, *a priori* we should not expect outh-going migration, assuming that the direction- termining factor is to be found in the physico- emical nature of the water. Thus, if the currents, nperature or salinity and the like were determining tors, we should expect, according to our present owledge of the hydrographical conditions at East land, a migration northwards in the direction ainst the water-masses which most nearly meet the uirements of the fish. As such a one-sided migration the north does not occur, we must either conclude t at a certain season at least there is a north- ng current, unknown to us, coming from the south ast[1]) along the bottom and moving up the east st; — or otherwise we must find another ex- nation.

In addition to the factors mentioned, one might nk of the light as a directive agency along the t coast southwards; the migration obviously takes ce especially in the last months of the year when position of the sun might be thought of perhaps having some influence after the urge to wander l set in. But in the present experiment we have pecimens which were taken in January-February t on the north coast, west of Langanes, and this he same time as the spawning was at the beginning the south coast in the case of other individuals nging to the same population marked. The light n orientating factor does not appear to come into sideration in these cases. We thus see that the tors mentioned, which vary regularly at the son when the migration evidently takes place which might be considered as influencing the ction, do not seem to explain why the Plaice the east coast migrate as they do. Other ularly varying factors, which might come into sideration, do not seem to be present.

f therefore we exclude inherited memory of the h, sense of direction etc., there seems for the ment, with the knowledge we have of the hydro- phy of East Iceland, only the one explanation sible, that a somewhat haphazard scat- ng takes place from the place of mark- on the east coast both to the north and e south; but the more intensive fishery on the of South Iceland presents the greatest chances recoveries from there. We may therefore imagine, as the emigrating Plaice from the Vopna Fjord on come out to the depth which for the moment s them[2]), a scattering takes place both to the north and south, and the topography of the coastal banks thus becomes apparently the determining influence in the migration picture, at least until the warmer water masses are reached; for example, the individuals met with along the south coast cannot find other places, if they follow a certain isobath (< abt. 400 m.) southwards. We may add, that even if there were really a greater migration southwards than northwards, this was to be expected, as the marking experiments (both in 1905 and 1931) were carried out on the south side of the Vopna Fjord; hence the emigration from the fjord to a certain depth, which would then be kept, would probably result in more going to the south than to the north.[3])

It is quite a different question whether the north-going Plaice succeed in spawning at the north coast before the urge to migrate ceases (perhaps owing to unfavourable outer conditions); the capture of large old specimens up to 4 years after marking on the Langanes ground (1905 experiment) indicates that this does not happen in all cases.

2. Length of Migration.

As the distance from the Vopna Fjord to the most frequented spawning places on the south and west coasts is between ca. 150 and 400 miles, we find here some of the longest known migrations for the Plaice. The longest migration undertaken by the Plaice marked by Johs. Schmidt in 1905 was about 375 miles; the specimen was retaken off Skagi on Reykjanes. Presumably as mentioned this specimen has wandered southwards round the island, but a migration round the north is in itself just as conceivable, as the distance there is but a little longer. The actual distance covered has been naturally considerably greater, as the Plaice on migration may be considered to follow almost the same isobath. In the 1931 experiment 5 individuals have wandered about 315—320 miles, one about 280 and one about 250 miles; all the others have covered less than 200 miles. As shown in Table 3 half of the recaptures in the course of the first year were made in the fjord area itself where the marking was carried out and the wanderings here are less than 10 miles; presumably these individuals have withdrawn into deeper water in the fjord for the winter and then returned to the coast in the following summer.

From this region we have hydrographical investiga- on the bottom conditions for April to September, not for the autumn and winter.

[2]) We may note, that Kyle has pointed out the importance of the pressure for the spawning and that Garstang has introduced the term "eubathic sense" for the hypothetical power of the Plaice to seek an optimum depth according to their size.

[3]) To throw light possibly on this interesting point, in the summer of 1933 I marked a number of Plaice both on the north and south side of the Fjord.

3. Velocity of Migration.

To determine the rate of migration per day we have a number of records, in great part, however, of little value as so long a period has elapsed between marking and recapture that one may conclude, that the Plaice either have not been under way the whole time or have wandered along quite different lines than the shortest. Unfortunately it is not possible for several reasons to use the present material for a definite statement of the maximum rate of wandering: (1) we do not know when the wanderings began after the marking; (2) nor do we know how long the Plaice have been on the grounds where they were retaken; (3) exact information regarding the line of direction between liberation and recapture is wanting; (4) there is also the possibility of error in the statements of position and date of recapture given by skippers.

Table 4 gives a summary of the average mileage covered in a day by individuals which have exceeded 100 miles; those which have gone a less distance have all a lower average than those noted in the table, indicating that they have either simply wandered around seeking food or begun their migration much later.

The individuals, which are of greatest value for a consideration of the spawning migration from east to south coast, are those which were unripe on marking[1]), but are specially noted from the south coast as ripe or nearly ripe fish. Of these we have 2, marked with a cross in the Table.

Table 4.

Velocity of Migration.

Final length and sex (cm.)	Supposed distance in miles		No. of days in the sea	Supposed lowest velocity miles per day	
× 46.3 ♀	178 S		148	1.2	(ripe)
34.0 ♂	190 N		197	1.0	
> 34.0 ♂	320 N		352	0.9	
× 36.5 ♀	170 S		209	0.8	(ripening)
41.6 ♂	250 S		311	0.8	
38.4 ♀	280 S		356	0.8	
36.9 ♀	315 S		380	0.8	
40.8 ♀	315 S		380	0.8	
42.8 ♀	115 N		166	0.7	
38.2 ♂	130 N		183	0.7	
34.0 ♂	315 S		424	0.7	
37.0 ♂	315 S		424	0.7	
42.8 ♀	175 S		285	0.6	
38.6 ♀	108	taken off S.E. Iceland	232	0.5	
> 47.0 ♀	122		263	0.5	
34.8 ♂	123		275	0.5	
43.7 ♀	123		275	0.5	
32.4 ♂	110		297	0.4	
41.6 ♀	121		303	0.4	
39.9 ♀	140		373	0.4	
33.2 ♂	140		401	0.4	

[1]) At East Iceland we have not found smaller individuals than ca. 40 cm. which could in any way be considered to have spawned.

The direction of migration is indicated by N. or S. With regard to the 2 individuals marked with a cross we know that the one was running (St. VI), the second ripening; these 2 belong among the Plaice which have migrated the most quickly, and they were retaken about the first of January and late in February, thus at the beginning of the spawning time, on the south coast. But only through repeated marking experiments on the east coast, also carried out during the months of September to December, perhaps longer, can we determine more precisely the point of time when the emigration from this region begins, if, that is to say there is a definite time for the emigration which is presumably the case to a certain extent.

In the 1905 experiment the first Plaice retaken on the south coast was captured on January 28th, thus 6 months after marking; the next (5) were retaken in the month of April. The greatest speed of travel was shown by the January individual, 1.4 miles per day (SCHMIDT l. c. p. 10).

We imagine that the emigrating stimulus sets in earliest at the height of the hydrographic summer on the N.E. coast, thus about October apparently. This would reduce the number of days used in migrating and presumably the greatest velocity per day should rather be increased to more than 2 miles per day as the distance travelled by the Plaice in most cases is certainly more considerable than that represented by a straight line. It is remarkable that all the specimens taken at S.E. Iceland, and none of the others have the lowest speed to show; possibly the actual time of starting of these has been somewhat later than that of the seemingly more speedy emigrants and consequently, the rate of travel is given far too low in the Table.

The 4 specimens in the above list which have wandered to the north coast and west coast were retaken in January-February and in July; their speed agrees with that found for the Plaice on the south coast and we may as to the specimens retaken in January-February conclude that they were in a hurry owing to the approach of spawning.

4. Season of Migration.

This subject has already been touched upon, but we may go a little deeper into the matter in considering certain recaptures from the 1905 as well as the 1931 experiments.

Table 5.

Recoveries according to season: 1905.
(Experiment made about August 1st).

August-September *1905*: no recaptures.
October: 1 spec. taken by English steam-trawler locality not stated, but the individual had left place of liberation ($^{29}/_{10}$).
November: 3 spec. taken in mouth of Vopna Fjor ($^{30}/_{11}$).
December: no recaptures.

uary *1906*: 1 spec. taken on south coast ca. 250 miles from Vopna Fjord ($^{28}/_{1}$).
ruary: no recaptures.
rch: no recaptures.
il-June: 8 spec. taken along south coast from Ingolfshöfði to Westmanna Isls. (ca. 170—280 miles from Vopna Fjord).
y: 2 spec. taken near place of liberation in Vopna Fjord.
gust-September: no recaptures.

Table 6.

Recoveries according to season: 1931.
(Experiment made about August 1st).

gust *1931*: no recaptures.
tember: 8 at the place of liberation.
ober: 1 spec. taken ca. 32 miles N. of Vopna Fjord ($^{30}/_{10}$).
ember: no recaptures.
ember: 1 ♀ ready to spawn taken on south coast ca. 178 miles S. of Vopna Fjord (ca. $^{29}/_{12}$).
uary *1932*: 1 spec. taken on north coast ca. 115 miles from Vopna Fjord ($^{16}/_{1}$).
ruary: 1 spec. taken on north coast 130 miles from Vopna Fjord ($^{2}/_{2}$).
spec. taken on north coast ca. 190 miles from Vopna Fjord ($^{16}/_{2}$).
almost ripe ♀ taken on south coast ca. 170 miles from Vopna Fjord ($^{28}/_{2}$).
h: 1 spec. taken on S.E. coast ca. 108 miles from Vopna Fjord ($^{22}/_{3}$).
l-June: 7 spec. taken on S.E. and S. coasts from Easter Horn to Portland (ca. 110—250 miles from Vopna Fjord).
spec. taken on E. coast ca. 55 miles from Vopna Fjord ($^{28}/_{4}$).
spec. taken on N. coast ca. 65 miles from Vopna Fjord ($^{22}/_{5}$).
: 1 spec. taken on W. coast ca. 320 miles from Vopna Fjord ($^{20}/_{7}$).
spec. taken on S. coast ca. 280 miles from Vopna Fjord ($^{25}/_{7}$).
spec. taken near place of liberation (< 35 miles to the north).
st-September: a number of recaptures (30) both at and near place of liberation, as also along the east and south coasts as far as 300 miles from place of liberation.

ing through these two lists and comparing them, e that in both periods the migration from east coast seems to begin in October; ndividuals nearest maturity obviously migrate hurry and reach as far as 180—250 miles from lace of liberation in about 2—4 months. In the experiment the individuals taken on the north show a distinct advance westwards in the course e months October—February.

Table 7.

Recoveries on north coast proper: 1931—32.

Date...	$^{30}/_{10}$	$^{16}/_{1}$	$^{2}/_{2}$	$^{16}/_{2}$
Distance from place of liberation (miles) ...	32	115	130	190

The distance travelled here on the north coast is certainly considerably greater, however, than the figures show, as the topography of the sea-bottom, according to earlier researches (SCHMIDT 1907, Pl. I), makes the Plaice wander far outside the straight route to the west; but a certain amount of parallelism between date and distance is unmistakeable.

Recaptures more than 9—12 months after marking have in this connection not much interest, since naturally we know less about the period these individuals have broken away from the place of liberation than we know about those taken in the course of the first 8 months or so.

To determine whether the departure from the East Iceland fjords also takes place at other times of the year than from October till on in the winter, a series of marking experiments at other seasons of the year would be interesting.

B. Age and Size of Plaice when migrating from the East Coast.

It is already known, that samples of Plaice taken at East Iceland contain for the most part individuals belonging to the year-groups up to about the VI-group[1]); it appears from the length distribution of the age-analysed material, that the largest individuals of the groups older than the V—VI-groups have left the district; yet we always meet with a number of large, even very large specimens of greater age; these old specimens are partly under, partly greater than 40 cm., up to 70—80 cm.; those below 40 cm. on the east coast are certainly always juvenile; and even among individuals of larger size than about 45 cm. one not seldom meets with some which obviously have never spawned.

So far as known, spawning Plaice have not been taken by research ships on the east coast of Iceland where, however, at least in certain years, spawning can take place to a very small extent, as mentioned elsewhere (TÅNING, l. c. 1929, pp. 13—17). Transport of fry from the spawning grounds on the warmer coasts of Iceland is, however, indispensable for the rich abundance of Plaice on the east coast. The scattered, very old Plaice, met with at East Iceland, and which certainly have spawned once or several times, may thus belong to the few spawners which have grown up and remained on the spot, or may have immigrated, e. g. from the south coast, after having spawned there once or several times. In SCHMIDT and SÆMUNDSSON (l. c. 1907 & 1913) re-

[1]) cf. TÅNING: l. c. 1929, p. 33 et seq., Tables XIII—XIV, pp. 109—110.

ference is made to a number of large Plaice of 40—52 cm. which were taken up to about 3 years after marking near to the place of liberation; a single specimen of 68 cm. was taken nearly 4 years after liberation and only about 30 miles from the place of marking and one might suppose that it had remained all the time on the east coast. A yearly migration to the south coast and back again to the east coast can hardly be undertaken by the species to any great extent. Of more than 2500 Plaice marked on the warmer coasts of Iceland so far but a single individual has been taken later with certainty on the north and east coasts, so that we have nothing to indicate that any great number of Plaice grown up in warmer waters have undertaken food-wanderings to the colder north and east coasts[1]). Naturally it does not follow from this, that Plaice which have left the colder region, where they have grown up, for the warmer region, should remain stationary in the latter after spawning. We know, however, nothing about this point.

Of the 61 Plaice recovered in the present experiment we have received the otoliths of 25 specimens; the ages will be found in the table p. 13.

A word may be interposed here with regard to the structure of the otolith as we may possibly manage from this, with a certain amount of probability, to determine if a spawning Plaice taken on the south coast has come from the east coast. These otoliths from Plaice marked in Vopna Fjord (and recaptured on the north, east or south coast), judging from the distance between the winter-rings, show a characteristic and comparatively good growth in the first 3—4 years (thus, whilst the fish are living in shallower water), then follow two or more rings close together; all the otoliths come from Plaice which have been migrating (taken by English or German trawlers or seiners of Danish nationality) and they all show a peculiar, irregular resorption along the margin.

The age lies between ca. 6 and 10 years, which falls in line with the information we have regarding the age of emigrants from the east coast as ascertained from trawl-caught and other samples. On looking through the table it will be seen, that it is not specially the oldest which migrate the farthest; for example, a couple of individuals of the VI-group have wandered 280 to 315 miles, whilst several of the X-group have stopped at S.E. Iceland. About a quarter of the material belongs to the X-group, i. e. the 1922 year class, which has been specially large at Iceland (v. Tåning l. c. 1929, Fig. 22, p. 85); that this group is still so strongly represented in 1932 at East Iceland comes naturally from the fact, that individuals in the cold region do not reach maturity on the whole so early as those in warmer waters.

[1]) In a marking experiment carried out at Ingolfshöfði no the south coast in July 1927 38.1 % recoveries have been made out of 250 marked Plaice, almost all at the place of marking, quite few to the west, but none to the east.

The youngest specimens, of 6—7 years on recapture, which have left the north-east coast, had a length of 29—41 cm. on marking and have certainly been, at the time they left the place of marking, about 32 cm. or more long (32.4—42.8 cm. on recovery). So far as the matter has been investigated, Plaice at Iceland appear to be mature for the first time at a size between 30 cm. and 45—50 cm., most, however, probably about 38—40 cm.; the Plaice mentioned, which have left the area at a length of over ca. 32 cm., have thus assuredly been driven to migrate by the beginning ripeness of the gonads, not to seek food. A few of the Plaice taken just in the neighbourhood of Vopna Fjord, however, have perhaps not migrated out to spawn but in search of food; on this point, though, we unfortunately know nothing, as the whole fish were not delivered to the laboratory. No marked Plaice of East Icelandic origin and less than 33 cm. has been taken on the spawning grounds of the south coast (cf. Table 1), which supports the view put forward, with respect to the minimum length of the emigrating Plaice.

The oldest individuals in the experiment, which have left the north-east coast, were about 10 years old, as mentioned, and they had a length on liberation of 36—45 cm. (on recapture ca. 40—46 cm.). A 10-year old and a 7-year old Plaice from the south coast are given as running ripe or near this condition (by respectively an English and a German fisheries investigations' authority).

We can thus sum up the foregoing review as follows: the majority of the Plaice have left the east coast as ca. 6—10 year old fish (> about 32 cm.) to proceed to the spawning grounds in warmer waters than the east coast offers in general; some few may get rid of their eggs on the east coast in certain years, but the possibilities for the eggs developing will usually be very small.

C. Rate of Growth in Length.

Sæmundsson (l. c. 1913, p. 5) states that the yearly growth of Plaice marked in Vopna Fjord is about 2.3 cm.

In the present material we have 42 records of the final size (usually stated in mm.). The length given for the Plaice on marking in the table (p. 3) is stated in cm., measured down to the nearest whole cm.; the average should thus be raised by 0.5 cm. But the measurement of living fish is not the same as that of dead, and we may reckon in most cases, that the length (for Plaice of the lengths mentioned) shrinks from the living to the dead condition by about 0.5 cm. (cf. Schmidt l. c. p. 9). We may therefore assume that the differences arising from measurement differences and from shrinking cancel each other, the more so as the measurements in a number of cases are not altogether trustworthy.

In the following Tables (8—10) the growth has been given for specimens of three categories: (1) stationary fish, (2) fish migrating northwards, (3) fish migrating southwards.

Considering only the average lengths of the specimens for which we have the initial and final measurements, we obtain the following average growth.

Table 8.

Average Growth.

Specimens:	Initial size	Final size	Growth
Stationary (16 spec.)	35.5 cm.	38.1 cm.	2.6 cm.
Migrated N. (7 spec.)	34.0 -	36.9 -	2.9 -
Migrated S.(18 spec.)	35.6 -	38.4 -	2.8 -

As not all the Plaice in this summarising table have passed through a whole growth period and some have passed about $1^1/_2$ periods, the results naturally are uncertain; yet they agree well with the growth given by SÆMUNDSSON, perhaps a little higher, which might be expected owing to the greater fishery now carried on by comparison with 25 years ago.

A more detailed consideration of the growth of the individuals stationary in Vopna Fjord when in September 1931 and others taken in August 1932 gives the following result.

Table 9.

Average length on liberation and recapture of recoveries in Vopna Fjord.

	retaken Sept. 1931 (7 spec.)	retaken August 1932 (9 spec.)
Aver. initial size.....	32.0 cm.	37.6 cm.
Aver. final size	32.9 -	41.6 -
Growth ...	0.9 cm.	4.0 cm.

In the course of the first month (August) the growth has been about 1 cm., whilst in the course of a whole year it has been 3—4 cm. for the stationary individuals; probably the greatest growth occurs in the summer and in the autumn, but as none of the stationary fish have been taken from late in September till early in August next year, we can say nothing definite about the matter.

For the individuals that have migrated the evidence is somewhat clearer; all those taken in the period from late in October 1931 to late in July 1932 had increased in length by 1.3 to 3.5 cm. (average: 2 cm.). As indicated in Table 10 we have only a couple of migrants (measurements known) taken late in 1931; but the figures seem to indicate, in spite of the shortcomings, that no essential change takes place between New Year until in the summer. It is not after June—July that growth begins again in the case of some individuals, while others still show further growth and this applies even to some of the Plaice which had reached the food-rich and warmer south coast. As shown by SCHMIDT (l. c. 1907, p. 10) likely any growth occurs during the long spawning

Table 10.

Growth in cm. of Plaice marked in Vopna Fjord, August 2nd—3rd, 1931.

Year	Month of recapture	Stationary	Migrated N.	Migrated S.
1931	August ...			
	September.	0.0-0.0-0.0-1.0-1.0-1.5-2.5		
	October...		2.7	
	November.			
	December .			1.3
1932	January...		1.8	
	February..		3.0-3.2	3.5
	March			1.6
	April			2.9
	May.....			1.7-1.8-1.8-2.4
	June			2.6*-2.6
	July.....		3.5	1.4*
	August....	1.5-2.0-3.0-3.0-3.0-4.0-6.0-6.2-7.3	1.3-4.5	2.8*-3.9-5.9*
	September.	4.0		4.2
	October...			2.0*-2.0*

* retaken on western part of south coast.

migration. Further investigation, however, is necessary as the number of measurements is still far too small. We should expect that the specimens, which come to the more westerly and warmest part of the south coast from the cold East Iceland (marked with an asterisk in Table 10), will grow specially strongly once they have had a little time to restore their energies after spawning; yet so far we have no distinct evidence of this. In this connection transplantation experiments would be of interest.

D. Intensity of Fishery.

These marking experiments are naturally too meagre to permit one to conclude anything, from the recaptures by the different countries fishing in Icelandic waters, with regard to their intensity of fishing within and outside the territorial limits on the different coasts; nor can they give any general picture of the intensity of the Plaice fishery at Iceland on the whole. To obtain such results we must have a longer series of experiments from all coasts.

The international statistics indicate, that the chief quantities of Plaice, now as earlier, are taken by British trawlers[1]) whilst only a small portion is taken by Icelandic, German, Dutch, Belgian and Danish. SÆMUNDSSON (l. c. 1913, p. 6) reports, that the recoveries in the marking experiments of 1904—05 at North and East Iceland were distributed as follows: ca. 75 % to British vessels, $12^1/_2$ to German and $12^1/_2$ to Icelandic.

[1]) 1929 ca. 84 %, 1930 ca. 76 %.

In the present experiment the British portion has fallen to ca. 26 % of the recoveries, the German to 5 %, whilst the remainder are almost equally divided among Icelandic, Danish and Faroese boats (with ca. 26, 23 and 20 %). But we note, on comparing the lists p. 13 with SCHMIDT 1907 and SÆMUNDSSON 1913, that the difference between 1905 and 1931 arises from the fact, that in 1905 there was no coastal fishery of importance at N.E. Iceland whereas it had grown to considerable importance in 1931—32. Of the Plaice which have migrated some distance out on the banks British vessels have taken about 60 %, whilst German and Danish vessels have taken the remainder.

The table below gives the recoveries by the different countries in the various years of the experiments of 1905 and 1931 in Vopna Fjord. As noted above, *494* Plaice were marked in 1905, *227* in 1931.

Table 11.

Recaptures by vessels of different countries in experiments of 1905 and 1931.

Retaken in	British	German	Icelandic	Faroese	Danish	Total recaptured	% of markings
1905.....	4					4	0.8
1906.....	4	7	2			13	2.6
1907.....	10	2				12	2.4
1908.....	7					7	1.5
1909.....	1					1	0.2
Total...	*26*	*9*	*2*			*37*	*7.5*
(%)...	(70.3)	(24.3)	(5.4)				
1931.....		1	8	1		10	4.4
1932.....	16	2	8	13	12	51	22.5
Total...	*16*	*3*	*16*	*14*	*12*	*61*	*26.9*
(%)...	(26.2)	(4.9)	(26.2)	(23.0)	(19.6)		

The recovery percentage in the 1905 experiment was 7.5, in the 1931 experiment 26.9 (and some recoveries from the latter have still to come); in the course of about $1^1/_2$ years ca. 3.5 % were recaptured in 1905, ca. 26 % in 1931, indicating a greatly increased fishery. One may add, however, that knowledge of the marking experiments and interest among the fishermen in 1905 and following years were scarcely so widespread as now; it is certain that far more of the returns 25 years ago went astray than has been the case recently. The 1931 experiment has still some results to come in, as the marking experiments at Iceland in the later years (even if made on other coasts) have yielded up to 47 % recaptures and recoveries have continued to be made up to 3—4 years after marking.

Summary.

1. Marking of 227 Plaice at N.E. Iceland in 1931 has shown, like the corresponding experiments in 1905, that Plaice approaching maturity for the most part migrate away from the cold east coast.

2. The migrating individuals have been chiefly taken on the warmer south coast, but emigration northwards round Iceland also takes place, and it is suggested that an equally intense fishery on all the coasts would show an approximately equal dispersion of the Plaice from N.E. Iceland to the north and south, regard being taken of certain local conditions.

3. The greatest distance of migration is about 300 miles; the greatest rate of migration per day has been $>$ 1.2 miles.

4. Emigration from the N.E. coast seems to take place mainly in the autumn (and winter).

5. The migrating Plaice have an age of ca. 6—10 years ($>$ ca. 32 cm.); no young Plaice appear to leave the east coast on food wanderings.

6. The yearly growth of Plaice on the east coast seems to be quite 3 cm. for individuals of 30—50 cm. in length.

7. Migrating Plaice probably grow somewhat less during the period when migration and reproduction take place.

8. In the course of the first $1^1/_2$ years after beginning of the experiment ca. 26 % of the marked fish have been recaptured; within the same period of time in the 1905 experiment at the same place only about 3.5 % of the marked fish were retaken.

Liberation: Vopnafjord, 65°44.5′ N. 14°45′ W. August 2nd—3rd 1931.
laice marked Da. 14201—14427. 227 specimens liberated, 61 recovered up to Febr. 1st 1933.

Recovery:

o. on abel	Locality (and Depth)	Position (approximately) Lat. N.	Long. W.	Date and year	No. of months in the Sea	Distance of Migration in miles	Sex	Initial and ultimate size in cm.	Ultimate age in years (Otolith)	Fishing vessel
4204	Off E. Horn	c. 64°25′	14°20′	$^{27}/_{5}$ 32	10	>110	♂	30—32.4	$7^{2}/_{12}$	E.
4205	Off Olfusá	c. 63°50′	21°15′	$^{1}/_{10}$32	14	>315	♂	32—34.0	$5^{6}/_{12}$?	D.
4210	Vopna Fjord (8 m.)		—	$^{4}/_{9}$ 32	13	< 10?	(♂)	31—35		I.
4216	Vopna Fjord		—	$^{2}/_{9}$ 32	13	< 10	(♂)	29—?		F.
4218	Vopna Fjord (37 m.)		—	$^{3}/_{9}$ 31	1	< 10	(♀)	32—?		I.
4220	Finna Fjord (68 m.)	c. 66°06′	15°06′	$^{30}/_{10}$31	3	> 32	(♂)	33—35.7	$7^{7}/_{12}$	F.
4227	Off Ingolfshöfði (170—200 m.)	63°47′	16°04′	$^{28}/_{2}$ 32	7	>170	♀[1])	33—36.5	$6^{11}/_{12}$	G.
4228	Vopna Fjord (28 m.)		—	$^{2}/_{9}$ 31	1	< 10	(♂)	35—36		I.
4230	Off Þistil Fjord (106 m.)	66°26′	15°21′	$^{27}/_{5}$ 32	10	> 65	(♂)	37—?		E.
4231	Vopna Fjord		—	$^{3}/_{9}$ 31	1	< 10	♂	30—30		I.
4255	Vopna Fjord		—	$^{23}/_{8}$ 32	$12^{2}/_{3}$	< 10	(♀)	47—50		I.
4264	Vopna Fjord		—	$^{21}/_{9}$ 31	$1^{2}/_{3}$	< 10	(♂)	31—32.5		I.
4268	Hjeraðsflói	65°43′	14°20′	$^{13}/_{8}$ 32	$12^{1}/_{3}$	> 17	(♀)	28.9—35.0		F.
4269	Off Stokksnes (W. Horn) (73 m.)	64°15′	14°35′	$^{5}/_{5}$ 32	9	>123	♂	33—34.8	$6^{1}/_{12}$	E.
4276	Off Seydisfjord (135 m.)	65°30′	12°55′	$^{28}/_{4}$ 32	9	> 55	♀	34—36.9	$9^{1}/_{12}$	E.
4278	Vopna Fjord		—	$^{20}/_{8}$ 32	$12^{2}/_{3}$	< 10	(♀)	45—47		I.
4280	Nyps Fjord (27 m.)	c. 65°48′	14°48′	$^{18}/_{7}$ 32	$11^{1}/_{2}$	< 10	♀	36—?		D.
4281	Vopna Fjord		—	$^{2}/_{9}$ 32	13	< 10	(♀)	32—?		F.
4282	Vopna Fjord		—	$^{23}/_{8}$ 32	$12^{2}/_{3}$	< 10	(♀)	32—35		I.
4283	?	?	?	abt.$^{2}/_{5}$ 32	9	?	♀	36—38.1	$7^{1}/_{12}$?	E.
4295	Vopna Fjord		—	$^{22}/_{8}$ 32	$12^{2}/_{3}$	< 10	(♂)	38—42		I.
4299	Vopna Fjord (22 m.)		—	$^{3}/_{9}$ 31	1	< 10	♂	29—30		I.
4305	Off Horna Fjord (55 m.)	c. 64°10′	15°10′	$^{11}/_{8}$ 32	$12^{1}/_{3}$	>140	♀	36—39.9	$10^{4}/_{12}$	D.
4306	Bakka Fjord (37 m.)	c. 66°02′	14°51′	$^{1}/_{8}$ 32	$12^{1/2}$	> 28	♀	31—35.5	$6^{5}/_{12}$?	D.
4309	Vopna Fjord		—	$^{12}/_{8}$ 32	$12^{1}/_{3}$	< 10	(♂)	37—44.3		F.
4313	Vopna Fjord		—	$^{2}/_{9}$ 32	13	< 10	(♂)	29—?		F.
4314	Off Axar Fjord (101 m.)	66°42′	16°45′	$^{16}/_{1}$ 32	$5^{1}/_{2}$	>115	♀	41—42.8	$6^{10}/_{12}$	E.
4316	Vopna Fjord		—	$^{20}/_{8}$ 32	$12^{2}/_{3}$	< 10	(♀)	43—46		I.
4318	Off Westmanna Isls.	c. 63°30′	20°10′	$^{25}/_{7}$ 32	$11^{2}/_{3}$	>280	♀	37—38.4	$7^{4}/_{12}$?	D.
4323	Off Stokksnes (W. Horn) (70 m.)	64°18′	14°41′	$^{2}/_{6}$ 32	10	>121	♀	39—41.6	$10^{2}/_{12}$	E.
4325	Off Ingolfshöfði (55 m.)	63°49′	16°24′	$^{15}/_{5}$ 32	$9^{1}/_{2}$	>175	♀	41—42.8	$10^{1}/_{12}$	G.
4326	Vopna Fjord (Fagridalr.)	c. 65°48′	14°22′	$^{8}/_{8}$ 32	12	< 10	(♀)	38—39.5		F.
4331	Off Olfusá	c. 63°50′	21°15′	$^{18}/_{8}$ 32	$12^{1}/_{2}$	>315	♀	31—36.9	$7^{3}/_{12}$?	D.
4332	?	?	?	?/$_{9}$ 32	13?	?	(♂)	29—?		E.
4333	Vopna Fjord		—	$^{21}/_{8}$ 32	$12^{2}/_{3}$	< 10	(♀)	29—35		I.
4335	Brede Fjord (66 m.)	65°20′	24°29′	$^{20}/_{7}$ 32	$11^{2}/_{3}$	>320	(♂)	34—?		E.
4336	Bakka Fjord	c. 66°06′	15°00′	$^{3}/_{8}$ 32	12	> 25	(♂)	33—34.3		F.
4338	Vopna Fjord (18 m.)		—	$^{3}/_{9}$ 31	1	< 10	(♀)	35—35		I.
4339	Vopna Fjord		—	$^{2}/_{9}$ 32	13	< 10	(♀)	33—?		F.
4347	E. of Ingolfshöfði	63°45′	16°20′	abt.$^{2}/_{12}$31	5	>178	♀[2])	45—46.3	$9^{9}/_{12}$	G.
4352	?	?	?	? 32	?	?	(♂)	35—?		E.
4356	Off Portland (104 m.)	63°23′	19°03′	$^{10}/_{6}$ 32	$10^{1}/_{3}$	>250	♂	39—41.6	$10^{2}/_{12}$	E.
4358	Nyps Fjord (27 m.)	c. 65°48′	14°48′	$^{18}/_{7}$ 32	$11^{1}/_{2}$	< 10	♀	31—?		D.
4359	Vopna Fjord		—	$^{25}/_{9}$ 31	$1^{2}/_{3}$	< 10	(♂)	29—31.5		I.
4362	Off Malmey (123 m.)	66°12′	19°50′	$^{16}/_{2}$ 32	$6^{1}/_{2}$	>190	♂	31—34.0	$7^{10}/_{12}$	E.
4364	Vopna Fjord		—	$^{2}/_{9}$ 32	13	< 10	(♀)	41—?		F.
4372	Off Axar Fjord (159 m.)	66°22′	16°55′	$^{2}/_{2}$ 32	6	>130	♂	35—38.2	$7^{10}/_{12}$?	E.
4378	Vopna Fjord		—	$^{7}/_{8}$ 32	12	< 10	(♂)	36—?		F.
4382	Vopna Fjord		—	$^{7}/_{8}$ 32	12	< 10	(♂)	29—35.2		F.
4385	Off Ølfusá	c. 63°50′	21°15′	$^{1}/_{10}$32	14	>315	♂	35—37.0	$10^{6}/_{12}$?	D.
4389	Vopna Fjord		—	$^{25}/_{9}$ 31	$1^{2}/_{3}$	< 10	(♂)	35—35		I.
4399	Vopna Fjord		—	$^{2}/_{9}$ 32	13	< 10	(♂)	37—?		F.
4405	Vopna Fjord		—	$^{2}/_{9}$ 32	13	< 10	(♀)	42—?		F.
4461	Off Stokksnes (W. Horn) (73 m.)	64°15′	14°35′	$^{5}/_{5}$ 32	9	>123	♀	42—43.7	$10^{1}/_{12}$	E.
4463	Off Horna Fjord	c. 64°10′	15°10′	$^{8}/_{9}$ 32	13	>140	♂	29—33.2	$6^{5}/_{12}$?	D.
4495	Off W. Horn (46 m.)	c. 64°18′	14°48′	$^{23}/_{4}$ 32	$8^{2}/_{3}$	>122	♀	47—?	$10^{1}/_{12}$?	E.
4496	Off E. Horn (66 m.)	c. 64°27′	14°23′	$^{22}/_{3}$ 32	$7^{2}/_{3}$	>108	♀	37—38.6	9	E.
4498	Off Ølfusá	c. 63°50′	21°15′	$^{18}/_{8}$ 32	$12^{1}/_{2}$	>315	♀	38—40.8	$8^{5}/_{12}$?	D.
4509	Eiðisvik	66°15′	14°40′	$^{24}/_{7}$ 32	$11^{2}/_{3}$	> 31	♀	34—37.5	$7^{4}/_{12}$	D.
4513	Vopna Fjord (44 m.)		—	$^{17}/_{11}$32	$15^{1}/_{2}$	< 10	(♀)	33—?		D.
4517	Vopna Fjord		—	$^{23}/_{8}$ 32	$12^{2}/_{3}$	< 10	(♂)	29—?		I.

[1]) ripening. [2]) ripe (maturity stage VI).

E. British Steam Trawler.
G. German — —
I. Icelandic Fishing vessel.
D. Danish Fishing vessel.
F. Faroese — —
— retaken near place of liberation.

( ) sex noted during marking only, not fully reliable.
c. Position not given directly by fishermen.
Age given in years reckoned from April 1st.

V

REPORT CONCERNING THE ANALYSIS OF COD OTOLITHS FROM ICELAND

BY

ÁRNI FRIÐRIKSSON, PAUL M. HANSEN, ANTON FR. BRUUN
AND
Å. VEDEL TÅNING

Foreword

by

Å. Vedel Tåning.

Whilst the age-analysis of the younger Cod is usually fairly reliable, as can be judged from the act that determinations effected by several persons ive very nearly the same result, the determination f the age of older Cod has revealed great differences. o reach better agreement, if possible, and to see ow great or how small the differences would be etween several persons examining independently the ame material and, eventually, to find some means f improving upon the methods used, the late Pro- ssor Johs. Schmidt arranged in 1932, and in January 933, for an otolith analysis to be carried out by vestigators who had been studying the Cod from ie North Western Area in recent years. The following port was drawn up and given to Professor Johs. CHMIDT whose desire it was, that the investigation should be made available to others engaged in the study of the Cod.

At the meeting of the International Council in Paris (May 1933) I gave a brief account of this investigation before the North Western Area Committee and showed some few preparations (Rapp. et Proc.-Verb., Vol. LXXXV (III), p. 7, 1933). Before the publication of the following report, delayed by the sudden death of Professor Schmidt, two very interesting works on the use of the otoliths have appeared from the Norwegian side; these also emphasize the importance of the otoliths in age-analyses and open up valuable perspectives for a development of their use (cf. Fiskeridirektoratets Skrifter. Serie Havundersøkelser. Vol.IV. No. 1 and 3. Alf Dannevig, Gunnar Rollefsen).

Report.

The material was collected at South Iceland on pril 9th and 14th, 1932, thus during the spawning me of the Cod. One sample (No. 1 of 110 spec.) was ken 9/IV off Landeyjasandr, 4 other samples (Nos. —5 of 71, 76, 46 and 47 spec.) were taken 14/IV on e spawning grounds at Westmanna Isls. The mate- al, which was fished by the patrol vessel "Þor", was ocured by Mag. Árni Friðriksson.

Its treatment has proceeded in the following anner.

The 4 investigators, A, B, C and D, undertook an alysis of the material independently of each other d in the manner usually employed by us. In this e otolith is broken across, the broken surface und smooth if necessary (but usually best left ground) and the otolith examined with binocular croscope against a dark background under a strong ht, directed against the median side of the otolith g. 1); steeping in alcohol or damping of the broken face with alcohol has proved advantageous and s been used in the examinations.

The first determination was carried out in 1932 d the results were handed over by each investigator Professor Johs. Schmidt. At a meeting on January , 1933, the results along with the original material re given to us and then a comparison was made of the determinations, leading to a discussion of the problems which had arisen therefrom. A further examination of the whole material by the different investigators was then made, again independently (2nd determination), and various preparations were specially made to help in clearing up the discrepancies which had appeared in the analyses. The analyses are given in the tables of the Appendix; the results are summarised below.

Table 1 shows the percentages given by the investigators (A, B, C and D) to the respective age-groups (III—XX); under ? are noted the percentages of deformed otoliths and those that could not be referred with any degree of probability to one or other age-group. The majority of the otoliths belong to the VIII—X groups, from 82.6—88.9 % as given by the different investigators. There is good agreement as to the size of the VIII-group; but the IX-group shows up as extremely variable in A—D and it is clear, that A—C have obviously referred a large number, given by D in the IX-group, to the X-group (see below); B and C are in fair agreement with regard to the grouping of the sample and A is most nearly in agreement with them.

In order to obtain a view of the degree of accuracy in the analysis of the individual otoliths the following

Table 1.

Age-grouping of 350 otoliths (Westmanna Isls. 1932) in %.
(Analyses made by independent investigators in 1932.)

Age-group	A	B	C	D
?.....	1.1	—	3.4	0.6
XX.....	0.3	0.3	0.3	—
XIX.....	—	—	—	—
XVIII.....	—	—	—	0.3
XVII.....	—	0.3	—	—
XVI.....	0.3	—	—	—
XV.....	1.7	0.3	0.6	0.3
XIV.....	—	1.1	—	—
XIII.....	4.0	2.0	2.2	1.4
XII.....	0.3	2.3	0.3	1.1
XI.....	—	4.3	2.6	1.4
X.....	**68.9**	**51.1**	**52.6**	**30.9**
IX.....	**0.6**	**13.1**	**17.4**	**37.7**
VIII.....	**20.3**	**16.9**	**16.8**	**17.4**
VII.....	0.3	4.3	2.9	4.9
VI.....	1.7	2.2	1.1	2.9
V.....	0.6	1.1	—	1.1
IV.....	—	—	—	—
III.....	—	0.3	—	—

arrangement of the material was made. In the 5 samples taken separately the agreement between the four investigators amounted to these values (Tables 3—4).

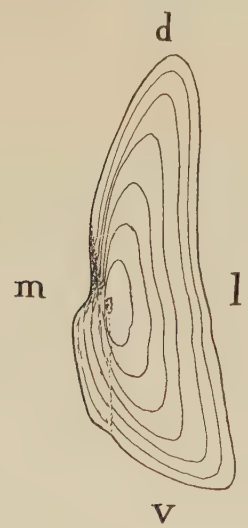

Fig. 1. Sketch of a transversal section of a Cod otolith; d: dorsal, l: lateral, m: median, v: ventral side.

Fig. 1.

Table 3.

Full agreement between all four (A+B+C+D).

Sample No. 1.....	21	cases in	110	or	19.1 %
2.....	16	—	71	-	22.5 -
3.....	18	—	76	-	23.4 -
4.....	17	—	46	-	37.0 -
5.....	20	—	47	-	42.5 -
Total...	92	cases in	350	or	26.3 %

Table 2.

(As Table 1, but analyses made in January 1933; see text below.)

Age-group	A	B	C	D
?.....	1.4	0.9	1.4	4.3
XX.....	0.3	0.3	0.3	—
XIX.....	—	—	—	—
XVIII.....	—	—	—	—
XVII.....	—	—	0.3	—
XVI.....	—	—	—	—
XV.....	0.3	0.3	0.6	0.3
XIV.....	—	—	—	—
XIII.....	3.4	2.3	3.7	1.4
XII.....	1.1	1.4	0.9	1.1
XI.....	0.6	2.6	5.1	1.1
X.....	**66.6**	**62.2**	**59.4**	**33.5**
IX.....	**1.4**	**6.6**	**6.3**	**32.3**
VIII.....	**20.9**	**18.0**	**16.9**	**17.7**
VII.....	1.1	2.6	3.1	4.6
VI.....	2.9	1.1	1.1	2.6
V.....	—	1.1	0.9	1.1
IV.....	—	0.6	—	—
III.....	—	—	—	—

Table 4.

Agreement in statements of age-group, but slight uncertainty in the case of one or more determinations (which have been indicated by a ?).

Sample No. 1.....	32	cases in	110	or	29.1 %
2.....	19	—	71	-	26.8 -
3.....	22	—	76	-	29.0 -
4.....	18	—	46	-	39.1 -
5.....	21	—	47	-	44.7 -
Total...	112	cases in	350	or	32.0 %

This agreement in the determination of the otoliths speaks in favour of their use, at least in these waters, and their utility goes at least as far as the X-group, so far as investigations have gone at Iceland. There most Cod spawn for the first time at 8 years old or 1—2 years older, and thus a fairly certain determination up to the X-group renders it possible to follow them until they appear on the spawning grounds. To this we may add, that the age-analysis of certain samples from West Greenland proves that a determination can be made with considerable certainty up to an even greater age; this was further confirmed by a common observation of a series of ground sections of otoliths from West Greenland Cod of about 13—17 years old.

After a discussion of the problems which had arisen, the whole material, as mentioned above, was again analysed by all four investigators independently. The result obtained is shown in Table 2. As might be expected, the discussion of the various problems has led to some changes in the conclusions with regard to the rings and thus with regard

to the size of the IX- and X-groups, though the size of the VIII-group remained practically unaltered[1]).

The great mass of the material thus falls, in both series of determinations, in the VIII—X-groups, namely about 81—90 % of the whole, as follows:

Table 5.

	A	B	C	D
1st determination...	88.9	86.8	82.6	83.5 %
2nd — ...	89.8	81.1	86.8	85.0 -

With regard to the weakly represented earlier age-groups (< VIII) and older age-groups (> X) it may be remarked, that the investigators have somewhat more of the groups VII, XI and XIII than of the remainder, but the material is so limited that we can hardly say more than that greater disagreements appear to exist between A, B, C and D with regard to the specimens older than about 10 years; this would indicate that the age-analysis of Cod older than 10 years is liable to greater error than the analysis of Cod of 1—10 years old; thus, according to our knowledge of the age of spawning for the Cod at Iceland, difficulties arise in trying to determine the age correctly after the Cod has once spawned.

A closer view of the agreements can be obtained by bringing together all the cases, where any one of the investigators is agreed with any one of the others, or with two of the others and finally with all three.

Table 6 gives a complete summary of all the full agreements in which at least two investigators have agreed as to the age of the fish, whether in the first determination (italics) or in the second (heavy). Lastly, the figures in ordinary type indicate each investigator's own agreement between first and second determination.

Table 6.

Summary of full agreement between any two investigators, at the first determination (1932, italics) and at the second determination (1933, heavy type). Figures in ordinary type give investigator's agreement with himself in first and second determinations. All in percentage.

	A	B	C	D
.....	82.3	*56.9*	*52.3*	*38.9*
.....	**70.3**	65.7	*46.9*	*44.0*
.....	**65.4**	**66.6**	58.3	*34.0*
.....	**37.1**	**39.1**	**37.1**	68.6

The reason why the last-mentioned determination has not been 100 % may be sought in three factors. Firstly, a number of the otoliths were undeterminable, which meant great uncertainty in the first and second examination so that they could not be included in the series of agreeing otoliths. Secondly, the investigators during the discussions between the first and second determinations have changed somewhat their ideas with regard to the structure of the otoliths; lastly, any observation is subject to some extent to the personal equation which can easily lead to a difference in two determinations following one another.

It would appear now from Table 6, that the percentage agreement between two of the investigators is not an absolute measure of the divergence in the main results of the analysis (cf. Table 1), which can be seen from the fact, for example, that B and C, who agreed best together in the main result in first determination, are less in agreement than A and B or A and C when each case is considered singly.

Table 7.

Summary of full agreement between three of the investigators and between all investigators.

	1st determination	2nd determination
ABC	42.9 %	62.0 %
ABD	32.6 -	33.4 -
ACD	30.0 -	33.4 -
BCD	28.9 -	33.7 -
ABCD	26.3 -	31.1 %

In the first determination, according to the foregoing, all four investigators agreed in 26 % of the cases, and in the second determination the corresponding value was 31 %; on the whole therefore there has not been much change with regard to the certainty in the determination of the otoliths showing clear and unequivocal ring-formation in the marginal zone as well. Full agreement in both first and second determination amounted to 24 % of the cases.

The agreement between the three investigators A, B and C is, however, much greater in the second determination than in the first and greater than between any three other combinations of investigators, namely full agreement in 62.0 % of the cases and almost full agreement in 72.9 % against 42.9 (and 55.4 %) at the first determination. The reason for this lies mainly in the clearing up of the position during discussions with regard to the outermost ring in the otolith.

In the following table we shall now summarise numerically the cases where the various investigators have expressed doubt with regard to their determinations, in 1932 and 1933. The table thus shows the number of cases where the investigator (A, B, C or D) has been in doubt, whether to a small or large extent.

Table 8.

Sample	1st determination							2nd determination						
No.	I	II	III	IV	V	Total	%	I	II	III	IV	V	Total	%
A	17	16	15	4	4	56	*16*	16	14	24	5	8	67	*19*
B	16	18	20	1	7	62	*18*	15	9	15	1	2	42	*12*
C	37	19	27	8	13	104	*30*	20	18	27	8	9	82	*23*
D	9	5	6	1	3	24	*7*	33	25	21	16	15	110	*31*
Average...						61.5 = 17.6 %							75.3 = 21.5 %	

[1]) This group (1924 year-class) has been proved to be dominant for a series of years especially on the east coast of Iceland and at West Greenland.

The different investigators have thus differed considerably in their uncertainty estimate, this varying between 7 and 31 % of the whole material. In the second determination the investigators have been on the whole more critical, so that the figures are not quite comparable. One may note, that whilst B and C showed a slight decrease in uncertainty, A and especially D show an increase, which is connected with their original, extreme positions with regard to the distribution of the specimens in groups IX and X.

Examination of the figures from the two determinations of the material (350 otoliths) further shows, that the four investigators had the following number of full agreements in the age-groups taken separately; the last column gives the variation in number of otoliths referred to the age-groups by A, B, C and D (whole material).

Table 9.

Age-group	1st. deter.	2nd deter.	Variation i No. in A, B, C & D
> X.....	0	0	14— 38
X.....	65	70	108—233
IX.....	1	0	2—132
VIII.....	24	38	59— 73
< VIII.....	2	1	9— 31
	92 = 26.3 %	109 = 31.1 %	

It appears clearly from this as from the above-noted age-grouping (Table 1), that the differences between the investigators have mainly come from the decisions as to the IX- and X-groups; A has had a tendency to refer the majority to the X-group, whilst D has referred many of them to the IX-group.

The obvious differences in the results reached by A and D might be considered of fundamental importance, since the difference lies in judging individuals of the IX- and X-groups. The figures from the first determination (Table 1) show that in A and D these two groups account for 69.5 % and 68.6 % of the material, but A reckons 68.9 %, D only 30.9 % to the X-group. B and C have respectively 64.2 % and 70.0 % for the two groups together, with respectively 51.1 % and 52.6 % in the X-group. The corresponding figures from the second determination (Table 2) show that these two groups together are credited with 68.0 and 65.8 % in A and D respectively, but A has 66.6 %, D only 33.5 % in the X-group. B and C have 68.8 and 65.7 % in these two groups together, with respectively 62.2 % and 59.4 % in the X-group.

Sample No. 3 was now chosen for a preliminary test and this was analysed anew by the four investigators (2nd determination), the determinations being in great part settled after an independent examination by each one. It then appeared, that D considered as a secondary ring (thus belonging to the 9th) what A regarded as the 10th winter ring, whereas B and C took up an intermediate position, as in certain cases where only a narrow summer ring was apparent on the margin of the otolith without any distinct winter-ring outside, they had referred these to the IX-group[1]). As noted before, B and C in the first analysis of the material had reached almost the same result with regard to the three dominant groups (see Table 1); yet in the judgment of the individual otolith, however, some disagreements appeared between B and C just as between the others.

Against the view that the outermost ring mentioned was a secondary ring, as maintained by D, it might be said, that the earlier analyses of Cod from both Iceland and Greenland (made in 1924—30) displayed a specially great occurrence of the X-group (year-class 1922), which at places had given up to 50—80 % in the product of the fishery, whereas the IX-group (year-class 1923) might beforehand be expected to be feeble, as it had been inconsiderable in the catches at most places and in one year only (1929) had appeared with about 30 % at North-west Iceland[1]). It might be maintained against this, naturally, that a lack or weakness of the year-class 1923 in the earlier samples, examined at Iceland and Greenland, could not exclude the possibility that this year-class had grown up at places from which we had no samples. The material collected at Iceland-Greenland came from widely separated places, which reduces the probability of such a concealed reserve. One might indeed think of the more remote Icelandic banks, from which we had little material, as the home place of such reserves. At West Greenland, from which samples have been examined yearly since 1924, or East Greenland with samples from Angmagssalik, the year-class 1923 has not been prominent; on the contrary poor. Thus the place where this year-class may have grown up, is not known.

Against the above-mentioned view of the outermost ring it might also be said, that it is not very common to find secondary rings so clear between the outermost rings of fish over about 8 years, as usually occurs in the present instance. The majority of the investigators at any rate have not previously remarked; that a secondary ring could appear with such distinctness and so constantly, with such a high percentage, at this spot in otoliths from these areas; but this exceptional occurrence might be imagined to have arisen from one and the same exceptional outer factor acting on individuals in a larger region.

It is apparent from the length distribution in the IX-group (Table 10), especially in the case of D, that a transference of individuals from the X to the IX is very possible. The great difference in the lengths of Cod reared on the different coasts of Iceland might well explain this condition, as the Cod wander from these feeding grounds to the south coast.

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[1]) It is doubtful, however, whether a summer-ring is ever laid down already early in April at Iceland; B and C have imagined that this might happen in the case of Cod which had come from the cold coasts to the warmer south coast in the first part of the year.

[2]) See TÅNING 1931, Medd. fra Komm. f. Danmarks Fiskeri- og Havundersøgelser, Fiskeri Bd. IX, Nr. 3, pp. 12 & 20.

Table 10.

ength distribution within the three principal age-groups, as given by the four investigators.

5 cm roups	A			B			C			D		
	VIII	IX	X	VIII	IX	X	VIII	IX	X	VII	IX	X
05—109			1			1			1			1
00—104			4		1	4			5		2	4
95— 99			18		2	15			16		11	14
90— 94			19		2	22		3	23	1	15	11
85— 89	6		61	9	12	49	6	5	49	8	40	30
80— 84	13		55	17	11	48	6	11	45	18	43	27
75— 79	20		18	19	7	18	18	8	17	18	15	10
70— 74	14	1	2	7	3	3	9	2	1	11		3
65— 69	2	1		2	1		1	1		2	1	
	55	2	178	54	39	160	40	30	157	58	127	100
er. length	77.2	—	86.0	79.0	83.2	86.0	77.7	81.5	86.4	78.7	85.4	86.7

These objections are thus unable to rebut the view, at the outermost ring may be a secondary ring.

To approach in a different way the subject the ring formation in the outer zone of the olith, some samples of otoliths were selected (by which had been determined twice by all four in-stigators independently, and which had resulted in rtly disagreement, partly full agreement with regard the outer ring. Of these otoliths sections were ound to a thickness of ca. 0.2 mm. (Fig. 2), and mounted preparations, which showed a trans-rsal section of the whole otolith, were then ex-ined by all four investigators independently of each er[1]). Both samples and ground sections were nbered in such a way, that the investigators did know which were theirs or the others from the lier determinations. The result worked out as ows:

Table 11.

Control experiment with otoliths. No. 1.

	A	B	C[2])	D
1st determination	10	10	10	10
2nd —	10	10	10	10
Ground section..	10	10	10	10
1st determination	10	10	10	9
2nd —	10	10	10	10
Ground section..	10	10	10	9(→10)
1st determination	10	10	(9←)10	10
2nd —	10	10	10	10
Ground section..	10	10	10	9(→10)
1st determination	10	10	10	9
2nd —	10	10	10	9
Ground section..	10	10	10	10

The sections were examined with the aid of the oscope; they were examined again later, without ge in result, in Edinger's projecting apparatus and s Epidiascope. Professor O. B. Bøggild, Mineralogical eum, kindly allowed the preparations to be made on grinding machines of the Museum.

It should be noted, that C chose the samples 1—4.

In the case of sections 2 and 3 D has noted, that there is a faint possibility of 10 winter rings being present; the 10th ring, regarded as secondary, is present along the dorsal margin of the otolith.

This control experiment showed in the first place, that ground sections of these older Cod seem to be better suited for the analysis of ages than the broken sections, which have otherwise been used. In the second place, the experiment shows, that whilst A and B (as also C) have always had the same opinion with regard to the outer ring and taken it as a 10th winter ring, D's view varied with a bias towards either 9 or 10, presumably influenced by the ability of the preparations to show the relative breadth of the outermost rings.

Thereafter a series of ground sections was made, including some otoliths which presented difficulties in determination; some sections failed, but 26 sections of the Icelandic sample remained.

Table 12.

Control experiment No. 2. (cf. Table 11).

No.		A	B	C	D
5	1st determination	10	10	10	10
	2nd —	10	10	10	10
	Ground section..	10	10	10	$\underline{9\text{-}10}$[1])
6	1st determination	10	10	10	10
	2nd —	10	10	10	10
	Ground section..	10	10	10	$\underline{9\text{-}10}$
7	1st determination	20	20	20	18
	2nd —	20	20	20	17-20
	Ground section..	20	20	20	19-20
8	1st determination	10	10	10	10
	2nd —	10	10	10	10
	Ground section..	10	10	10	9-10
9	1st determination	10	10	10	10
	2nd —	10	10	10	10
	Ground section..	10	10	10	$\underline{9\text{-}10}$

[1]) The line underneath indicates that this figure is most probably the correct one.

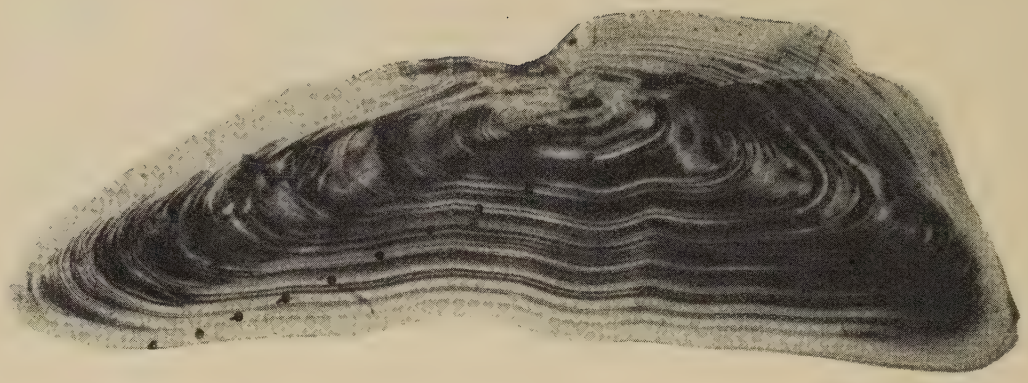

Fig. 2 a.

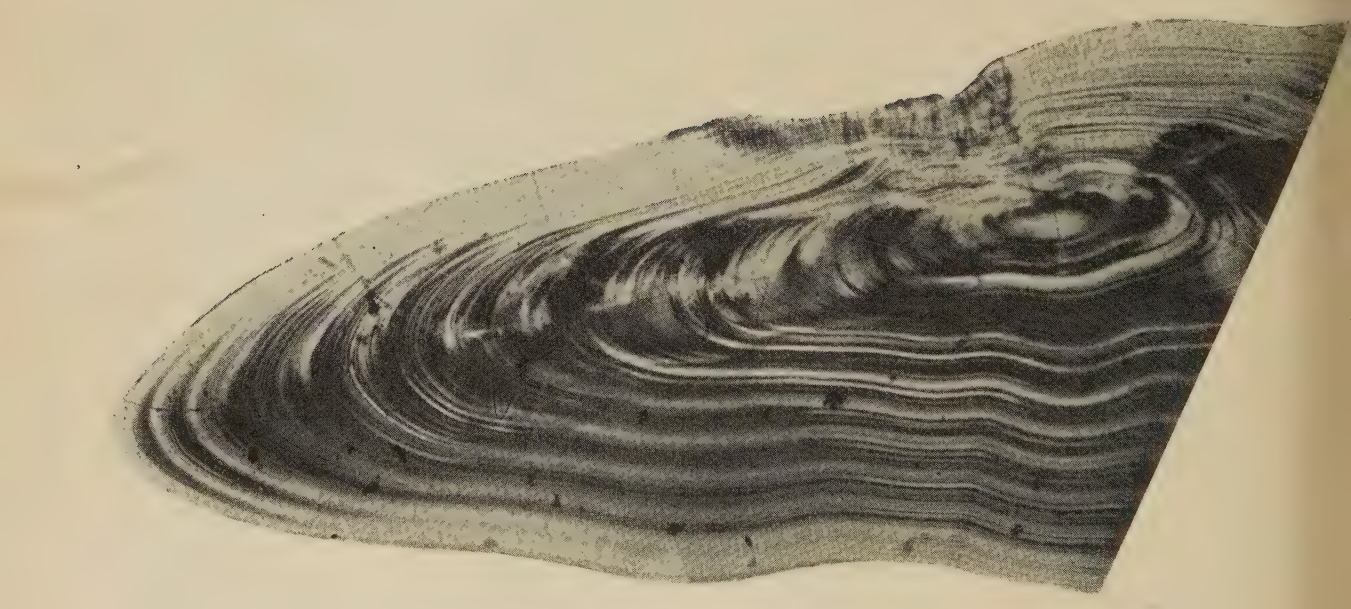

Fig. 2 b.

Fig. 2. Ground sections of Cod otoliths.
a. Otolith No. 3 (Table 11). The dots indicate winter rings. b. Otolith No. 4 (Table 11). Transmitted light (Photo: A. Bruun).

No.		A	B	C	D
10	1st determination	10	9	9-10	9
	2nd —	10	9	9	9
	Ground section..	10	9(?)	9-10	8
11	1st determination	10	10	10	9
	2nd —	10	10?	10	9
	Ground section..	10	10	10	9
12	1st determination	10	10	10	9
	2nd —	10	10	10	9
	Ground section..	10	10	10	9
13	1st determination	8	8?	8	7
	2nd —	8	8	8	7
	Ground section..	8-9	8	8	8
14	1st determination	10	10	9-10	9
	2nd —	10	10?	10	9
	Ground section..	8-9	9?	10	9?
15	1st determination	10	9	9-10	9
	2nd —	10?	10	10?	9
	Ground section..	10	10	10(11)	11
16	1st determination	10	10	9-10	9
	2nd —	10	10	9?	9
	Ground section..	10	10	10	9
17	1st determination	10	9	9	9
	2nd —	(9)10	10	9	9
	Ground section..	9-10	9	9	9
18	1st determination	10	10	9-10	9
	2nd —	10?	10	10	9
	Ground section..	10	10	10	9?
19	1st determination	10	10	10	9
	2nd —	10?	10	10	9
	Ground section..	10	10?	10	9-10
20	1st determination	10	9?	9	9
	2nd —	10	9	9	9
	Ground section..	10	10	10	9-10
21	1st determination	10	10	11-12	10
	2nd —	10	9	10	10
	Ground section..	10-11	10	11	10
22	1st determination	10	10?	9-11?	9
	2nd —	10	9-10	10?	9
	Ground section..	10?	9?	10	9-10
23	1st determination	10	9	9	9
	2nd —	10?	9	9	9
	Ground section..	10	10(9)	10	8-9
24	1st determination	(9)10	9	9	9
	2nd —	9?	10	9-10	9
	Ground section..	9-10	10(9)	9-10	9
25	1st determination	10	9	9	9
	2nd —	9-10	9	9	9
	Ground section..	10	8?	10	9-10
26	1st determination	8	8	8	8
	2nd —	8	9	8	8
	Ground section..	8	8	8	8

No.		A	B	C	D
27	1st determination	10	10	10	10
	2nd —	10	9?	10	10
	Ground section..	10	10	10	9(10)
28	1st determination	10	10	10	8
	2nd —	10	10	9-10	8-9
	Ground section..	9-10	9	10-11	9-10
29	1st determination	10	10	9	9
	2nd —	10	9	10	9
	Ground section..	10?	10	9-10	9
30	1st determination	10	10	9-10	10
	2nd —	10	9(10)	01	10
	Ground section..	10	10	10	9

Generally speaking the determinations (Table 12) repeat the results obtained by the first examination and show, that D has a tendency to estimate the number of rings a little lower than A, B and C. The last three maintain in most cases the primary value of the outermost ring.

Scale samples of the Cod Nos. 1—4 in the ground preparations as also of about 20 others from the material were cleaned, bleached and mounted in glycerine, then examined by means of microscope, Edinger's projecting apparatus and the Zeiss Epidiascope. The results were much more indefinite than in the case of the otoliths and the determination of the number of winter rings lay in most cases 1—2 below that reached from the otoliths (8—12 winter rings). As all four investigators were agreed, that the use of the scales was of much less value than the otoliths, no further work was done with them.

In concluding the investigations each of the participants has endeavoured to weigh up the determinations, including 8 for each otolith, and to take out those which might be considered to some extent certain. From the whole material first of all, A, B, C and D have cut out respectively 16.3, 28.6, 18.9 and 25.4 %, as being more or less unusable to judge from the 8 determinations; those excluded nevertheless arrange themselves very much in the same way as the dominant age-groups. The rest of the material was then divided over the respective age-groups as shown in the following Table (in percentages).

Table 13.

Proportion of age-groups in the material.

Age-group	A	B	C	D	Average
XX	0.3	0.4	0.4	0.4	*0.4*
XV	0.3				*0.1*
XIII	1.7	1.0	1.1		*1.1*
XI	0.3	0.4	0.4		*0.3*
X	71.5	69.6	71.1	72.5	*71.2*
IX	4.4	5.2	4.9	5.0	*4.8*
VIII	19.1	21.2	20.4	20.3	*20.2*
VII	1.0	0.8	1.1	1.2	*1.0*
VI	0.7	0.4	0.4		*0.4*
V	0.3	0.4	0.4	0.8	*0.5*

It will be seen, that in this weighing-up of the material the four investigators come to almost the same result, namely, that the VIII-group amounts to about 19—21 % and the X-group to about 70—73 % of the whole material, whilst the IX-group only reaches some 4—5 % and the remaining groups still less.

Table 14 gives further a view of the number of determinations belonging to the VIII—X-groups, but so divided in sub-groups that one can see whether one or perhaps several of the 8 determinations might indicate, that the structure of the otolith permits the possibility that it belongs to one of the adjacent age-groups. The Table has been drawn up on the basis of the above-noted distribution of the usable determinations of all four investigators.

Table 14.

Determinations divided in sub-groups.

Age-group		No. of otoliths (average)
X	perhaps older	9
	exactly X	70
	perhaps younger	115
IX	perhaps older	11
	exactly IX	1
	perhaps younger	1
VIII	perhaps older	12
	exactly VIII	29
	perhaps younger	15

Whilst the VIII gives the distribution one might expect in a normal case of determinations with some uncertainty attached, the results for the IX and X-groups yield a clear impression of the above-noted uncertainty with regard to the outermost ring. We may conclude therefore, that the ring formation in the marginal zone presents a problem that requires further investigation.

Owing to the extremely variable natural conditions one finds on the coasts of Iceland and Greenland we may expect, that correspondingly the formation of winter and summer rings in the Cod otoliths will also vary in regard to point of time and in its whole structure — according to the conditions under which the individual Cod live. These conditions have not been studied in detail, whilst the formation of the rings is also imperfectly known, especially in the period when the Cod — owing to approaching maturity and subsequent emigration from the cold coasts — changes to the spawning places in the warmer regions, where the altered natural conditions may be considered to effect a great change in the forming of the otolith rings. Presumably one will find an advance in the time for the ring formation, just as the structure, e. g. the relative breadth of the rings laid down in this period, probably differs from that seen in otoliths of more or less stationary, immature fish. It seems to be the case that the winter rings, laid down in the period when the fish is proceeding to spawn for the first time, may have such an appearance that a confusion of primary and secondary rings may easily occur.

We propose therefore, that the following methods should be adopted for the investigation of these conditions, since we are of the opinion that an accurate and uniform age-analysis can only be made when these questions are cleared up for the Iceland-Greenland region.

1. The time of deposition of winter and summer rings should be determined by the collection of material throughout the entire year, as far as possible, and at a series of localities on all coasts.

2. It is proposed, that Cod of 4—6 years old (ca. 35—75 cm.) should be marked at different places at Iceland and Greenland; during the marking scales should be taken to make a first determination of the age. Later investigation of the otoliths, which may be received from the recaptures, especially the ripe individuals, will present the possibility of obtaining information of considerable importance regarding the ring formation in the marginal zone, first and chiefly regarding the condition of the secondary rings.

3. An investigation is proposed with the object of determining whether the first-time spawning in itself has any influence on the formation of rings immediately before, during and after this. The investigation is imagined carried out by the collection of material of Cod, approaching the spawning time, spawning fish, recovering spents and of first spawners (8 year Cod smaller than e. g. 80 cm.), marked on the spawning ground but recovered later in the same or following year. Younger Cod to be collected at the same time for comparison.

4. In these and other age-analyses of Cod it is recommended, to as great an extent as seems necessary to use ground sections of ca. 0.2 mm. thinness from the middle of the otolith, as these sections have proved their value especially in judging of the marginal zones; similarly, special rings (laid down in certain years) stand out very distinctly in these sections with regard to breadth and clearness and thus in many cases help to make the determination more secure. The sections, probably just as well as the scales, can be used for the calculation of the growth in the various growth-periods of the fish. With suitable, technical material such a section can be prepared in ca. 10 minutes. They can be examined by means of an Edinger apparatus.

5. It is recommended that, in future determinations, a uniform mode of description should be used in designating the ring structure of the otoliths, for example, as indicated in the following list of abbreviations.

c. 3-4 secondary ring between 3rd and 4th winter ring; probably not primary ring, hence not included in the stated number of winter rings.
c. r supposed secondary ring in marginal zone, not included in figure.
10 9 or 10, probably 10.
9-10 9 probably correct.
10) but very slight probability for 10.
quite uncertain.
ef. deformed otolith, indeterminable.
to indicate, that the outermost winter ring lies on the margin of the otolith.
v) or to indicate, that the noted winter or summer ring is specially prominent.

Whilst otoliths from these northern waters, with r example about 10 winter-rings, may be very clear ground sections and very valuable, often showing the rings of the marginal zone specially distinctly, the scales of Cod of this age, according to our investigations, are of very little value in the determination of the age, as it is just the rings of the marginal zone which are most often extremely indistinct and uncertain. On the other hand, the undernoted are agreed, that the investigation undertaken confirms the absolute value of the otoliths as a means of giving a view of the dominant year-classes within the Cod stock in these waters; nor do we doubt, that their value will be increased by closer studies, and we think it of very great importance for the continuity and uniformity in methods, that close co-operation should be maintained among the different investigators.

Árni Friðriksson. Paul Hansen.
Anton F. Bruun. Å. Vedel Tåning.

Carlsberg Laboratorium, 30. January 1933.

Summary.

The object of the investigation has been to examine, hat degree of accuracy could be reached by several fferent investigators in the independent analysis of aterial of otoliths (Cod of medium age); further, e aim has been to try and reach some common ay of judging the ring formation in otoliths from eland-Greenland, eventually to improve the methods study and to examine, how far the scales could taken as of equal trustworthiness with the otoliths r Cod of medium age.

It may be remarked at once, that the usefulness the otoliths (for the Cod examined: ca. 8—10 year l from Icelandic waters) greatly exceeds that of the ales, in that the rings of the marginal zone in the ter are as a rule extremely indistinct.

Four persons (A, B, C and D) examined the material ice (in 1932 and January 1933) independently of h other; the material consisted of 350 otolith and le samples from Iceland; none of the investigators d seen the results of the others in the interval; us, 8 completely independent determinations of each olith are available. The 8 determinations indicate, at 81—90 % of the material belongs to 8—10 ar-old Cod; the small remainder, apart from some ite indeterminable otoliths, consists of an equal ount of younger and older Cod. In both determina- ns of all 4 about 17—21 % of the whole material referred without any doubt to the VIII-group ar-class 1924). In considering the IX and X-groups a difference in principle has revealed itself in judging of the outermost ring of the otolith in certain, not too clear cases; A, B and C taking this ring as primary, D as secondary. This has led to a difference in the quantities ascribed to the two groups. All four, however, show full agreement in 26 and 31 % of the age-analyses in the two series of determinations. Omitting D, the agreements between the other three investigators are considerably higher, namely, full agreement in the two series of 43 % and 62 % of all cases. It is probable, according to the investigation, that about 70 % of the whole material belongs to the rich year-class 1922, which has been dominant in these waters for a number of years.

The use of otoliths in stock analyses of Cod must be considered as of considerable value, but the present investigation has shown, nevertheless, that a more penetrating study of the ring formation in otoliths is necessary in the Iceland-Greenland waters, with their greatly contrasting natural conditions, in order to remove as many shortcomings as possible. The investigation has given rise to a number of proposals, which if carried out would bring these age-analyses on to a firmer and more certain basis. It is proposed, for example, that the marking of Cod should be carried out in conjunction with the age-analyses, and ground sections of the older Cod otoliths are recommended for study.

Appendix.

List of Otolith determinations.

No.	Length	Sex	A 1.	A 2.	B 1.	B 2.	C 1.	C 2.	D 1.	D 2.
I.										
1	73	♀	8	8??	9	8	9?	8	8?	7-8
2	70	♀	8	6	6	4?	7?	5	6	6
3	74	♀	8	8	7	8	8	8	8	8
4	70	♂	8	8	7	8	7-8	7	8	(7)8
5	71	♀	8	8	8	8	8	8	8	8
6	67	♀	6	6	6	7	7	7?	7	7
7	64	♂	6	5-6?	5	5-6	6-7	5	5	4-5
8	65	♀	8?	8??	8	8	7-8	7	7	7
9	67	♂	5	5??	3	5?	6?	4-6?	6?	6
10	68	♂	7	7	7	7	7	7	7	6-7
11	62	♂	6?	6?	5	4-5	6	6?	5	5
12	65	♂	8	8	7	7	7	7	8	8
13	65	♂	5	6	5	5	6	5	5	5
14	73	♂	8	8	8	8	8	8	8	8
15	74	♂	10	10	10	10	10-11	10	10	10
16	74	♂	10	10	9	10	10	10	9?	9
17	73	♂	8	8	8	8	8	8	8	8
18	72	♂	9	8	9	8	8	8	8	8
19	74	♂	10?	10	10	10	9-10	9	10	9
20	74	♂	8	8	8	8	8-9	8	8	7(8)
21	73	♂	8	8	8	8	8	8	8	8
22	72	♂	8?	6?	7	6	8	7?	6	5-6
23	83	♂	10	10	10	10	10	10	9	10
24	83	♂	10	10	10	10	10	10	9	9
25	84	♂	10	10	10	10	10-11	10	10	9-10
26	82	♂	10	10	10	10	10	10	9	9-10
27	81	♂	8	8	8	8	8	8	8	8
28	83	♂	8	10	8	8?	8-9	9-10	8	8
29	80	♂	8?	10	10	10	9-10	9	8	8-9
30	81	♀	10?	10	11	9	9-10	11-12	9	8
31	84	♂	10	10	10	10	10	10	9	9
32	83	♀	def.	def.	??	def.	def.	def.	def.	def.
33	82	♂	10	10	11	10	10	10	9	9
34	82	♂	10	10	10	10	10	10	9	9
35	82	♂	10??	7?	7?	5??	8??	7?	6	5-6
36	83	♂	10	10	10	10	10	10	9	9
37	84	♂	10	10	10	10	9-10	10	9	9
38	82	♂	10	10	10	10	9	10	10	9-10
39	82	♂	10	10	10	10	10	10	10	10
40	81	♀	10	10	10	10	9-10	10?	9	8-10
41	83	♀	10?	10-13?	12	10	10?(12?)	11?	10	9-10
42	80	♀	10	10	10	10	10	10	10	9-10
43	81	♀	10	10	10	10	10	10	9	9-10
44	80	♀	8	8	8	8	8	8	8	8
45	81	♀	10	10	10	10	9-10	10	9	9
46	82	♀	10	10	10	9	11-12	10	10	10
47	82	♀	10	10	10?	9-10	9-11?	10?	9	9
48	82	♀	10	10	10	10	10	10	9	9-10
49	81	♀	10	10	10	10	10	10	9?	10
50	84	♀	8??	7	7	7	8-10?	8	6	6
51	85	♀	10	10	9-10	10	10	10	9	9-10
52	82	♀	8	8	8	8	8-9	8	8	8
53	82	♀	10?	8	8-9	8-9	9	9	8	8
54	87	♀	8	6	8	6	8??	7-8	6	6
55	85	♀	10	10	9-10	10	10	10	9	9-10
56	85	♀	8	8	8	8	8	8	7	7
57	87	♀	10	8?	10	5-8?	9	10?	8	6-8
58	85	♀	10	10?	9	10	10	10	10	9-10
59	87	♀	10	10	10	10	10	10	9	9
60	85	♀	10	10	10	10	10	10	10	10
61	88	♀	10	10	10	10	10	10	10	10
62	86	♀	10	10	9	10	10	10	9	9-10
63	86	♀	10	10	10	10	10	10	10	10
64	88	♀	10	10	8	10	10-11	10	10	10
65	87	♂	10	10	10	10	10	10	10	9-10
66	89	♀	10	10	10	10	10	10	10	9-10
67	88	♀	10	10	10	10	10	10	10	10
68	86	♂	10	10	9	10	10	10	9	9-10
69	86	♂	10	10	10	10	9-10	10	9	9-10
70	88	♂	10	10	10	10	10	10	10	10
71	89	♂	10?	10	11	10	11	11	9	9-10
72	86	♂	10	10	10	10	10	10	10	10
73	89	♂	10	10	10	10	10	10	10	10
74	85	♂	8	8	8	8	9	8	8	10
75	87	♂	10	10	10	10	10	10	9	10
76	97	♀	10	10	10	10	10	10	9	9-10
77	75	♂	6?	6	5	5-7??	8??	7-8	5	5
78	70?	♂	8	8	8	9	8	8	8	8
79	75	♂	8	8	8	8	8-9	8?	7	7
80	79	♂	10?	10	7	10	10	10	9	9
81	77	♂	8	8?	8	8	8	7	7	7
82	75	♀	10	10	10	10	10?	10	10?	10
83	75	♀	8	8	7	9?	9	9	8	8
84	79	♀	10?	10	8	10	9	10	8	8
85	76	♀	8	8	8	8	7-8	8	8	8
86	77	♀	8?	6-8	6	6-7	7??	6	6	6
87	76	♀	6	6?	6	6?	7-8	6-7	6	6?
88	77	♂	10	10	10	10	10	10	9	9
89	77	♀	10	10	10	10	10	10	9	9-10
90	75	♂	10	10	10	10	10	10	9	9
91	76	♂	8	8	8	8	8	8	8	8
92	75	♀	8?	8?	8?	8	8?	7-8?	8	8
93	75	♂	8	7-8	7?	7	7-8	8	7	7
94	102	♀	10	10	10	10	10	10	10	10
95	102	♀	10	10	9	10	10	10	10	10
96	103	♂	10	10	10	10	10	10	9	9-10
97	95	♂	10	10	10	10	10	10	10	10
98	97	♀	10	10	9	10	9-10	10	9	9
99	95	♀	10	10	10	10	9-10	9-10	9	9
100	96	♀	10	10	10	10	10	10	10	10
101	90	♂	10	10	10	10	9	10	9	9
102	91	♂	10	10	10	10	9	10	9	9-10
103	90	♂	10	10	11?	10-11	10	10-11	10?	10
104	92	♂	10	10	10	10	10-11	10	10	10
105	91	♂	(10?)12	13	12?	13	11??	13?	12?	12-13
106	93	♀	10	10	10	10	9-10	10	10?	10
107	92	♀	10	10	9	10	10	10	10	10
108	93	♀	10	10	10	10	10	10	10	10
109	91	♀	10	10	10	10	10	10	9	9
110	90	♀	10	10	9	10	10	10	9	9

Length Sex	A 1.	A 2.	B 1.	B 2.	C 1.	C 2.	D 1.	D 2.
76 ♂	10	10	8?	10	10	10	9	9
78 ♂	10	10	11?	10	11	10	10	10
76 ♂	8	8	8	8	8-9	8	8	8
76 ♂	8	8	8	8	8	8	8	8
76 ♂	10	10	9	10	9-10	10	9	10
75 ♂	10	10	10	10	10	10	9	9-10
76 ♂	10(12?)	10??	12	11-12	9	10-11	9	9
75 ♂	8	8	8	8	8	8	8	8
76 ♂	8	8	8	8	8	8	8?	8
72 ♂	8	8	8?	8	7-8	8	7	7
88 ♂	10?	10?	10?	10	10	11-12?	10?	10
74 ♂	8	8?	6	7	9	8-9	7	7
71 ♂	8?	8	10?	9	9	9?	8	7-8-9
79 ♀	10	10	10	9	9	10	9	9
79 ♀	10	10	10	10	9	10	10	9
78 ♀	8	8	8	8	8	8	8	8
77 ♀	8	8	8	8	8	8	7	7-8
87 ♀	8	8	8	8	8	8	8	8
89 ♂	10?	10	10	10	10	9-10	9	9-11
88 ♂	10	10	10	10	10	10	9	9
87 ♂	10	10	10	10	10	10	9	9-10
84 ♂	10	10	10	10	10	10	9	9
89 ♂	10	10?	9	9	9	9	9	9
87 ♂	8	8	8	8	8	8	8	8
87 ♂	10	10	10	10	10	10	9	9
81 ♂	10	10	10	10	10	10	10	10
89 ♂	10	10	10	10	10	10	10	10
82 ♀	10	10	9?	9	9	9	9	9
84 ♀	10	10	9	10	9-10	10	9	9
84 ♀	8	8	8	8	8	8	8	8
83 ♂	10	10	9	10	9-10	10	9	9
80 ♂	10	10	9	10	10	10	9?	9-10
80 ♂	10	10	9	10	9-11	9	9	9
82 ♂	8	8	8	8	8-9	8	8	8
84 ♂	10	9-10	9	9	9	9	9	9
84 ♂	10	10	10	10	10	10	9	9-10
82 ♂	10	10	10	10	10	10	9	9-10
83 ♂	10	10	10	10	9-10	9-10	8	8-9-10
80 ♂	(9?)10	9?	9	10	9	9-10	9	9
83 ♂	10?	8	8	9-10	8-9	8-9	8	8
81 ♂	8	8	8	8	8	8	7	7-8
80 ♀	10	10	10	10(11)	10	10-11	10	10
87 ♀	10	10	9?	(9)10	10?	10	9	9
87 ♀	13?	12?	10?	12?	10	12	9	9
85 ♀	10	10	10	10	9-10	10	9	9-10
88 ♀	10	10	10	10	10	10	10	10
88 ♀	10	10	10	10	10	10	10	10
88 ♂	10	10	10	10	10	10	10	10
96 ♂	(9?)10	10	10	(9)10	10	(8)10?	10	9-10
95 ♂	13?	12	12	11(12)	12	11?	9	11-12
95 ♂	13	11-12	13?	10	10	11	10	10
93 ♂	10	10	10	10	10	10	9	9-10
90 ♂	10	10	10	10	10	9-10	8	8-9
95 ♀	10	10	10	10	10	10	10	10
94 ♀	10?	10	10?	10	9-10	11?	11	10-11
95 ♀	13?	10	11	10	10?	11?	10?	10
90 ♂	10	10	10	10	10	10	9	8-9
93 ♂	10(11?)	11?	11	10	10-11	11	10	10
94 ♂	10	10	10	10	10	10	11	9-10
90 ♂	10	10	10	10	10	10	9	9-10-11

No.	Length Sex	A 1.	A 2.	B 1.	B 2.	C 1.	C 2.	D 1.	D 2.
61	94 ♂	16?	15	15	15	15	17?	15	14-15
62	95 ♀	10	10	10	10	10	10	10	10
63	95 ♀	10	10	10	10	10	10	10	10
64	98 ♀	10?	10-11	11	11	11	11	10	10-11
65	90 ♂	10	10	10	10	10	10	9	9-10
66	95 ♀	10	10?	11?	10	10-11	10	9	9-10
67	96 ♂	10	10	9?	10	9-10	9	9	9
68	99 ♀	13?	13?	14?	13(14)	11-12?	13?	13	13
69	103 ♂	13?	10-13?	11?	11?	11-14?	11?	10	11-12
70	103 ♂	15	13?	14?	13	11-14?	13?	12?	13?
71	101 ♂	10	10	10	10	10	10	9	9

III.

1	75 ♂	8	8	8	8	8	8	7	8?
2	77 ♂	8	8??	8?	7?	8	9?	7?	7?
3	75 ♂	10	10	10	10	10	10	10	10
4	76 ♂	10	10	10	10	10	10	10	10
5	76 ♂	10	10	10	10	10	10	10	10
6	76 ♂	8	8	8?	8	8	8	7	7
7	76 ♂	10	10	9?	10	10	10	10	10
8	77 ♂	8	8	8	8	8	8	8	8
9	77 ♂	8	8	8	8	8	8	8	8
10	76 ♂	8	8	8	8	8	8	8	8?
11	78 ♂	10	10	9	9	9-10	9	9	9
12	77 ♂	10	10	10	10	10	10	9	10?
13	72 ♂	10?	10?	10	10?	9?	11?	7	9?
14	72 ♂	8	10??	8	8?	7??	9?	7?	7(8)
15	72 ♂	?	8??	6??	8?	7??	8??	8?	8?
16	67 ♂	10	10	10	10	10	10	10	10
17	80 ♂	13??	10?	11	10	10	11?	10	10(11?)
18	84 ♂	10	10	10	9?	10	10	10	10
19	83 ♂	10	10	10	10	10	10	10	10
20	84 ♂	10	10	10	10	9-10	10	10	10
21	80 ♂	10	10	10	10	10	10	10	10
22	80 ♂	10	10	10	10	10	10	10	10
23	83 ♂	8-10?	??	9?	8	9?	9??	8	8
24	80 ♂	8	8	8	8	8-9	9?	8	8
25	84 ♂	10	10	10	10	10	10	9	9
26	83 ♂	10	10	10	10	10	10	9	9
27	81 ♂	10?	10??	9?	8-(9?)	9	9?(10)	10	10
28	81 ♂	10	10	10	10?	10	10	9	9
29	81 ♂	8	8	8	8	8-9	8	8	8
30	80 ♂	8	8	7?	7	8??	8(?)	6	(6)7?
31	81 ♂	10	10	10	10	10	10	10	10
32	82 ♂	10	10	10	10	10	10	9	9
33	81 ♂	8	8	7	8	8-9	8	8	8
34	81 ♀	8	8	8	8	8	8	8	8
35	84 ♀	8	8	8	8	9	8	8	8
36	83 ♀	10	(9)10?	9	9	9	10	9	(8?)9
37	83 ♂	10	10	10	10	10	10	9	9(10)
38	85 ♂	10	10	10	10?	9-10	10	9	9
39	86 ♂	10	10?	10	10	10	10	9	9
40	85 ♂	10	10	9	10	10	10	10	10
41	85 ♂	10	10	10	10	10	10	10	10
42	86 ♂	13(10?)	10	13?	10(11?)	10-11	11?	11	11
43	86 ♂	10	10	10?	11	10	10-11	9	9
44	88 ♂	10	10	10	10	10	10	10	10
45	89 ♂	10	10?	10?	10?	8-10?	10??	10?	10?
46	85 ♂	10	10	10	10	10	10	9	(9)10?
47	88 ♂	10	10?	10	10	9-10	10	9	9
48	85 ♂	10	8	8	8	9?	8	8	8
49	86 ♂	10	10	10	10	9	10?	9	9(10)
50	85 ♂	10	10	10	10	9-10	10	9	9?
51	86 ♂	?	10?	11?	11?	9??	10(?)	10	10

No.	Length Sex	A 1.	A 2.	B 1.	B 2.	C 1.	C 2.	D 1.	D 2.
52	87 ♂	10	10	10	9(10?)	9-10	10	10	10
53	86 ♂	8	8	7?	8	8	8	8	8
54	89 ♂	10	10	10	10	10	10	10	(9)10
55	86 ♂	10	10	10	10	10	10	10	10
56	87 ♀	10	(9)10	9	10	9	9	9	9
57	88 ♀	10	10	10	10	9-10	9?	9	9
58	85 ♀	10	10	10?	10	9-10	10	9	9
59	86 ♀	10	10?	9	10	9-10	10?	9	9
60	106 ♂	15?	13	14	13	13	13?	12	12
61	107 ♀	15?	13?	13	13	13	13?	13	13?
62	98 ♀	15?	13?	12	13-14	12-13?	13	13	13?
63	95 ♀	10	9?	9?	9	9-10	10?	9	9
64	99 ♀	13	13?	14?	13(14?)	13	14-15?	13	13
65	96 ♀	10?	10	10	10	10	10	10	10
66	97 ♀	10	10	10	10	10	10	9	9
67	98 ♂	13	13?	13?	12	13?(14)	13?	12	12
68	95 ♂	10	10?	10?	10	10-11??	10?	9	9
69	96 ♂	10	10	10	10	10	11?	10	10
70	90 ♀	13?	13??	13?	12	10-13??	12-14	10?	10?
71	96 ♂	10?	8?	9	8	10	8?	9	9
72	96 ♂	15	10?	12?	11?	10-12??	13?	9?	9
73	90 ♂	10	10	10	10	10	10	9	9?
74	90 ♀	10	10	10	10	10	10	9	9
75	90 ♀	10?	10?	12?	10	10?	10?	9	9
76	90 ♀	10	10	10	10	10	10	9	(9?)10

IV.

1	69 ♂	9	9	9	9	9	8	9	9
2	69 ♀	8	8	8	8	8	8	8	8
3	80 ♀	10	10	9	9(10)	9	9(10)	9	9
4	84 ♀	10	10	11?	10	10-11	10-11	9	9-10
5	73 ♂	8	8	7	8	8	8	8	8
6	74 ♂	8	8	8	8	8	8	8	8
7	75 ♂	8	8	8	8	8	8	7	7-8
8	81 ♀	10	10?	10	10	10	12-13	9	9?
9	80 ♀	10	10	10	10	10	10	10	10
10	75 ♂	8	8	9	8	8-9	8	8	8
11	81 ♂	8?	8	7	8	9-10	9	9	9
12	80 ♂	10	10	11	10	10	10	10	10
13	79 ♀	10	10	10	10	10	10	10	10
14	80 ♂	10	10	10	10	10	10	9	9
15	83 ♂	10	10	10	10	10	10	10	10
16	80 ♂	10	10	10	10	10	10	10	10
17	83 ♂	10	10	10	10	10	10	9	9
18	81 ♂	10	10	8	9	10	10	9	8-9
19	84 ♂	10	10	10	10	10	10	10	10
20	81 ♂	10	10?	10	10	10	12-13	10	10
21	81 ♂	10?	10?	8	10	9	10	9	9-10
22	78 ♂	8?	10	9	10	8	9-10	9	8
23	79 ♂	10	10	10	10	10	10	10	9-10
24	82 ♂	10	10	8	10	9-10	10	9	9
25	106 ♀	10	10	10	10	10	10	10	9-10
26	87 ♂	10	10	9	10	10	10	9	9
27	95 ♀	10	10	10	10	10	10	10	10
28	98 ♂	10	10	10	10	10	10	9	8-10
29	95 ♂	10	10	10	10	10	10?	10	9
30	93 ♂	10	10	10	10	10	10	10?	9-10
31	90 ♂	10	10	11	10	10	10	10	9-10
32	94 ♂	13?	10-12?	12	12	13	11-12	10	10?
33	85 ♂	10	10	10	10	10	10	10	10
34	87 ♂	10	10	10	10	9-10	10	10	10
35	85 ♂	10	10	10	10	10	10	9	9-10
36	86 ♂	10	10	10	10	10	10	10	10
37	86 ♂	10	10	10	10	9-10	9-10	9	9
38	86 ♂	10	10?	10	11	9-10	11	10	10?
39	87 ♂	10	10	10	10	10	10	10	9-10
40	86 ♀	10	10	10	10	10	10	9	10
41	86 ♂	10	10	10	10	9-10	10	9	9
42	89 ♂	10	10	10	10	10	10	9	9-10
43	89 ♀	10	10	10	10	10	10	9	9
44	88 ♀	8?	8	8	8	8	8	8	8
45	86 ♂	10	10	10	10	10	10	9	9-10
46	86 ♂	10	10	10	10	10	10	9	9

V.

1	79 ♂	10?	9	9	9	9	9	8	8
2	78 ♂	10	(9)10	10	10	9	9-10	8	8-9
3	80 ♂	10	8	9	8	8-9	8	8	8
4	83 ♂	10	10	10	10	10	10	10	10
5	77 ♂	8	8	8	8	8	8	8	8
6	77 ♂	8	8	8	8	8	8	8	8
7	72 ♂	6	6	6	6	6	6	6	6
8	77 ♂	10	10	10	10	10	10	10	10
9	79 ♂	10	8?	10	10	9	10?	9	9
10	76 ♂	10	10	10	11	10	10	10	10
11	76 ♂	10	10	10	9-10	10	10	9	9-10
12	75 ♂	10	10	10	10	10	10	9	9-10
13	80 ♂	10	10	10	10	10	10	10	10
14	83 ♂	10	10?	9?	9	9-10	10	9	9
15	82 ♀	10	10	10	10	10	10	9	9
16	84 ♂	10	10	9	10	10	10	9	9-10
17	80 ♀	10	10	9	10	9-10	10	9	9-10
18	81 ♀	10	10	10	10	9	10	10	(9)10?
19	84 ♀	10	10	10	10	10	10	9	9
20	80 ♂	10	10?	8	10	9-10	9-10	9	9
21	81 ♂	8	8	8	8	8	8	8	8
22	81 ♂	10	10	10	10	10	10	9	9
23	88 ♀	10	10	10	10	10	10	10	10
24	87 ♀	10	10	10	10	10	10	10	10
25	88 ♀	10	10	10	10	10	10	10	10
26	88 ♂	10	10	9?	10	9-10	10	9	9-10
27	87 ♂	10	10	10	10	10	10	10	10
28	85 ♂	10	10	9	10	10	10	9	9
29	86 ♂	10	10	10	10	10	10	10	10
30	85 ♂	def.	def.	def.	def.	def.	def.	def.	def.
31	88 ♂	10	8	10	10	9-10	9-10	9	9
32	89 ♂	8	10	8	8	8	8	8	8
33	86 ♂	10	10	10	10	10	10?	9	9
34	94 ♀	13?	?	13	12	12-13	13	11	10-11
35	92 ♀	13?	10?	13-14	10	12-13?	13?	10?	10-12
36	94 ♀	20	20	20	20	20	20	18	17-20
37	94 ♀	10	8	10?	8	8(10?)	8	9	8
38	91 ♀	10	10	10	10	10	10	9	9
39	94 ♀	10	10	10	10	10	10	10	10
40	91 ♀	10	10	10	10	10	10	10	10
41	93 ♀	10	10	10	10	10	10	10	9-10
42	94 ♀	10	10	10	10	10	10	10	10
43	91 ♀	10	8	10?	9	9	9	9	8-9
44	92 ♂	10	10	10	10	10	10	10	10
45	100 ♀	15?	13?	17?	13	13-18?	15?	13?	13
46	100 ♀	10	10	10	10	10	10	10	9-10
47	97 ♀	10	10	10	10	10(12)?	11-12	10	9-10

VI

THE CALCULATION OF AGE-DISTRIBUTION WITHIN A CK OF COD BY MEANS OF RELATIVELY FEW AGE-TERMINATIONS AS A KEY TO MEASUREMENTS ON A LARGE SCALE

BY

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Introduction.

Age investigations of cod are made with the double purpose of ascertaining, firstly, the year-classes present in catches on certain grounds and at certain times, and secondly to determine the percentages by which each year-class is represented. By investigating the age of a comparatively small number of fish, as compared to the total quantity of the catch, it will, as a rule, be easy to determine the composition as to year-classes. On the other hand it is difficult to determine the exact distribution of year-classes by other means than investigating each single cod caught, a method, however, which is not practicable, and we are thus forced to be satisfied with the approximate results arrived at by investigating minor samples representing the total catches as well as possible.

Three methods have been applied for investigating the age of cod: 1) Some have used the "Petersen-Method": by measuring a great number, and deciding the age according to the graph based on knowledge of the size of fish at different ages. 2) The second method: by counting the "winter-rings" of the otoliths cut and examined under a microscope. 3) By the third method the scales are subjected to treatment similar to that of the otoliths.

Whatever may be said elsewhere of the "Petersen-Method", it may safely be stated that it cannot be applied to age-investigations of cod in Icelandic waters, because any definite difference in the average length of neighbouring year-classes in a catch is much too small, or in other words: the variation in the length of fish of the same age is too great. The method I have used for age-investigations of Icelandic cod is the otolith-method, like Dr. Bjarni Sæmundson and the Danish investigators, and those, who have been engaged in age-investigations of Icelandic cod, will probably agree that the otoliths are, in most respects, much to be preferred to the scales for determination of age.

A Combination of two Methods.

It is obvious that it is possible to apply otolith-investigations to a comparatively small number of cod only, as the collecting of the otoliths is slow work in addition to being expensive, but most important is the fact that a great amount of time is required for work in the laboratory where usually the staff available is engaged on other work. Scientists, therefore, have had to be content with examining a reasonable number. To counteract the possibility of a small number of otoliths insufficiently representing the entire catch a great number of cod from this has been measured, and a comparison between the diagrams constructed from otolith-determinations and from measurements respectively will then show the value of the small sample as compared to the greater one. Two methods have thus frequently been combined, i.e. the "Petersen-method" combined with the "otolith-method" or the "scale-method".

Necessity of using the diagrams correctly.

Although precautions may be taken in selecting otoliths from fish representing a fair average of the catch in respect of size (and thus also to some extent age) the unavoidable result must be greatly lacking in accuracy. The otoliths represent, at the best, the fish caught at one place, on a single day, and perhaps fish of one particular fishing ground only. In 1932, for instance, I investigated the age of 870 codfish caught off Westmanna Islands. Assuming that there had been 70 fishing-days during the season, and on the average 100,000 fish had been caught each day, the total amount of cod caught at the place during the year 1932 would be 7,000,000. The average deviation in the age-investigations (870) is therefore $\sqrt{\frac{7,000,000}{870}}$ or about 90 times greater than it would have been if the investigations could have been carried out with absolute accuracy. During the same year (1932) I measured 6500 cod from the waters off Westmanna Islands, and it is obvious, that if an accurate investigation of all those fish had been practicable, the average deviation would have been 2.73 times less $\left(\sqrt{\frac{6500}{870}} = 2.73\right)$ than that of the otolith material alone. It is clear from this that it is of great importance to be able to use age-investigations on a few hundreds of cod as a key to measurements on a large scale, as by such method a great amount of labour is saved and the possibility of correct results as to the percentage of the year-classes in the catch is increased. Keeping this aim in mind I have developed a working-method which consists in calculating the percentage of each year-class in the total quantity measured, when the graph of each single year-class is known generally from otolith investigations at the time and place in question. In the following this method will be briefly explained and at the same time I shall try to point out its utility and how it may be applied.

Age-determination on a comparatively small number of fish, serving as a key to measurements on a large scale.

By the cod-investigations, I have carried out in Iceland since beginning my researches there in 1931, I have had the length of cod measured in full centimeters, following the rule of the International Council for the Exploration of the Sea of fixing the length of the fish at the whole figure below the actual measurement. A fish which is 50—100 cm. in length can easily measure one or two cm. more or less according to its position on the measuring-board or according to its condition. In order to prevent such deviations, but most of all, however, to get a good survey of the size, I have made it a rule to divide all the fish measured into 5 cm. size-classes. As a rule I use 8 size-classes, as in most places there are but few fish more than 100 cm. or less than 70 cm. in length. Therefore I class together all the fish that are above or below these limits, and indicate the different classes by letters.

H	100 cm. +	D	80—84 cm.
G	95—99 cm.	C	75—79 cm.
F	90—94 cm.	B	70—74 cm.
E	85—89 cm.	A	69 cm. —

If the number of fish in H is much higher than that in G, I subdivide H into new 5 cm. classes, as follows: H = 100—104, H_1 = 105—109, H_2 = 110—114, etc. In the same manner I divide A if necessary (A = 65—69, A_1 = 60—64, A_2 = 55—59 etc.).

Table 1.

Size-class cm.	a		b		x	y	y/x
	x_a	y_a	x_b	y_b			
H 100 +			1	5	1	5	5
G 95—99			5	20	5	20	4
F 90—94			10	50	10	50	5
E 85—89	1	4	17	68	18	72	4
D 80—84	8	32	34	136	42	168	4
C 75—79	9	360	3	120	12	480	40
B 70—74	7	210			7	210	30
A 69 -	5	95			5	95	19
Total.....	30	701	70	399	100	1100	
Percentage .	30	63.7	70	36.3	100	100	
Difference,%	+ 33.7		— 33.7		0		

Let us assume that 100 fish have been measured and their age determined, and that another 1000 have been measured only, then the total number of fish measured equals 1100. The figures in the size-classes of those fish whose age was determined (100) we will call x, and the numerical values in the size-classes of all fish that were measured (1100) we will call y. Moreover, let us assume that the age-investigations revealed that there are two year-classes only in the catch, a and b. In the table of the results of the age-investigations (Table 1), the numbers in each size-class of a and b are denoted by x_a and x_b. The table

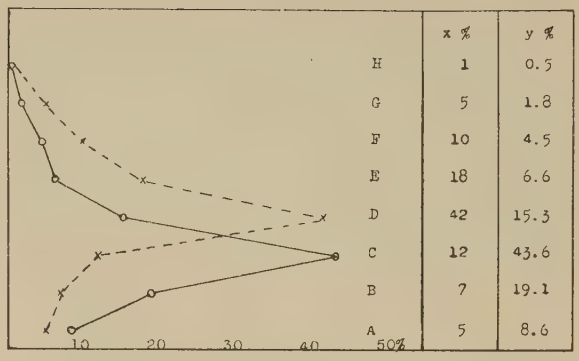


Fig. 1, illustrating Table 1. Class-distribution according to otolith sample: broken line, and according to measurements: full line.

shows that judging by the age-investigations there were 30 fish of age a, but 70 of age b, or 30 % and 70 % respectively. If the numeral series x and y are compared it is obvious that they differ to some extent i.e. x reaches maximum in the D-class but y in the C-class. From this it is clear, that the a-class is less representative than b. The y material is 11 times the amount of the x material and therefore 3.3 ($\sqrt{11}$ = 3.3) times more representative, and thus it is of great importance to examine what it can tell us about the accuracy of the results of the age-investigations. First of all, it is clear that too large a proportion of big fish, in comparison to the general proportion of fish in the sea, has been "chosen" for the examination of the otolith, and therefore it is to be expected that there will be less of the b-class and to the same extent more of the a-class, than the age-determinations show. On the other hand, there is nothing which consequently contradicts the fact that there is a natural proportion between a and b in *every single size-class*. It may be assumed therefore that the figures which represent a and b in each size-class are proportionately the same in x as in y, and in consequence the figures which represent a and b in each size-class in the x column, must be multiplied by a corresponding value y/x, that the number y which represents the age-group in this size-class of the graph may be found. If this multiplication of x_a and x_b in all size-classes is carried out new numeral series y_a and y_b appear. These new series indicate, within specific limitations, how many individuals of a and b there are in the total number of fish measured. As may be seen from the table, the result from these calculations is altogether different to the result given by the age-investigations, but that was to be expected as shown by the above calculations. The results before and after the calculations will be as follows:—

Age-group	According to otolith investigs.	Acc. to calculations	Difference
a	30 %	63.7 %	+ 33.7 %
b	70 %	36.3 %	— 33.7 %
Total:....	100 %	100 %	0 %

An Example of the Application of the above Method of Investigations.

In Bolungarvik in N.W.-Iceland, one of my stations for measuring cod, otoliths were taken from 100 cod and in addition 397 cod were measured (total 497). During the age-investigations of the 100 otoliths, 3 proved useless leaving 97 on which investigations could be made with comparative certainty. They were divided into age-groups as follows:—

Age in winters	Number	Percentage
8—	14	14.4
9.....	54	55.7
10.....	7	7.2
11.....	19	19.6
12+	3	3.1
Total.....	97	100.0

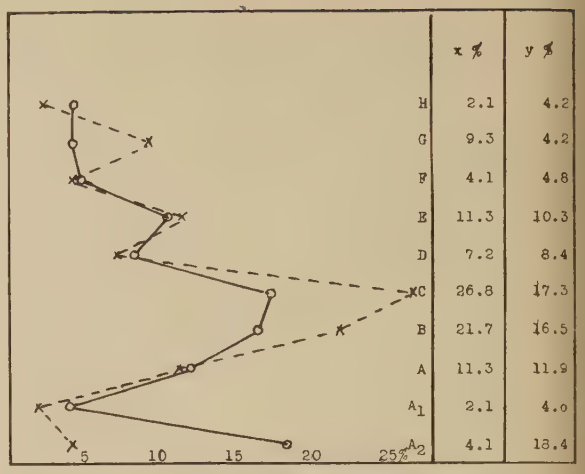


Fig. 2, illustrating Table 2. Class-distribution according to otolith sample: broken line, and according to measurements: full line.

Table 2. Cod, caught in Bolungarvik on April 15th, 1933.

Size-class cm.	8—		9		10		11		12+		x	y	y/x
	x_{8-}	y_{8-}	x_9	y_9	x_{10}	y_{10}	x_{11}	y_{11}	x_{12+}	y_{12+}			
H 100 +							1	10	1	11	2	21	10.5
G 95—99			1	2	2	5	4	9	2	5	9	21	2.3
F 90—94			2	12	1	6	1	6			4	24	6.0
E 85—89			6	28	1	5	4	18			11	51	4.6
D 80—84	1	6	2	12	2	12	2	12			7	42	6.0
C 75—79	4	13	17	56	1	3	4	13			26	86	3.3
B 70—74	3	12	15	58			3	12			21	82	3.9
A 65—69	2	11	9	49							11	59	5.4
A_1 60—64	1	10	1	10							2	20	10.0
A_2 59 —	3	68	1	23							4	91	22.8
Number	14	120	54	250	7	31	19	80	3	16	97	497	
Percentage.....	14.4	24.2	55.7	50.2	7.2	6.2	19.6	16.2	3.1	3.2	100	100	
Difference.....%	+ 9.8		— 5.5		— 1.0		— 3.4		+ 0.1				

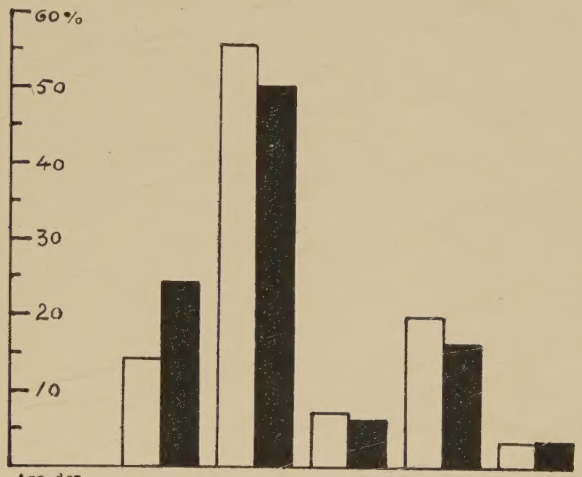
As the number of fish in the year-classes younger than 9 winters or older than 11 winters was comparatively small, I have combined them into two heterogeneous age-groups 8 — and 12 +, and thus there are 5 age-groups. As mentioned above, each age-group is divided into size-classes (cf. Table 2 and figure 2, x_{8-}, x_9, x_{10}, x_{11} and x_{12+}). The total sum of all classes (x and y) is similarly divided. On account of the great number of fish in the A-class this is subdivided into classes A, A_1 and A_2. The figures y/x are then calculated and the numerical value of x_{8-}—x_{12+} in each class is multiplied by the corresponding numerical value of y/x, thereby arriving at the numerical series y_{8-}—y_{12+} or the "calculated age-determination". By adding the figures in the y_8—y_{12} columns I arrive at the "calculated age-distribution" of the 497 fish measured. If we calculate, in percentage, the number of fish in each age-group we arrive at figures that do not correspond with the results of the age-investigations, but which may be supposed to be more correct. The difference between the age-investigations alone, on the one hand, and the calculated results on the other, is as follows (cf. Fig. 3):

Age	Accord. to otolith investig.	According to calculations	Difference
8 winters —	14.4 %	24.2 %	+ 9.8 %
9 winters	55.7 %	50.2 %	— 5.5 %
10 winters	7.2 %	6.2 %	— 1.0 %
11 winters	19.6 %	16.2 %	— 3.4 %
12 winters +	3.1 %	3.2 %	+ 0.1 %
Total:	100.0 %	100.0 %	0.0 %

Discussion of the Method.

The method is an attempt to calculate the age-distribution of a large number of measured fish by means of a numerically small sample of otolith determinations. The article seems to prove the necessity of applying some method but the extent to which the above method can be relied upon is a different question.

The material has been arranged according to 5 cm.-classes in order to have a fairly large number of each age-group in each. The results might, however, have been somewhat different if the range of the cm.-classes had been 2 cm. only and another result, again, might have been arrived at if the division had had other limits as for instance 72, 77, 82 cm. etc. As to which division being the best I believe this depends to some extent on the diagrams of the length-distribution, a question that should be thoroughly investigated.



Age-determined	%	14.4	55.7	7.2	19 6	3.1
Calc.	%	24.2	50.2	6.2	16.2	3.2
Diff.		+ 9.8	- 5.5	- 1.0	- 3.4	+ 0.1
Age		8-	9	10	11	12+
Year-class		1925+	1924	1923	1922	1921-

Fig. 3. Diagram showing the difference between age-distribution according to otoliths only (white columns) and that calculated by the method described (black columns).